U.S. Department of Energy
Office of Environmental Management

Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Implementation Guide

Revision 1
August 2013

REVISION LOG

Date	Reason for Revision
Revision 0, March 2008	• Initial issue of EM guide
Revision 1, August 2013	• Updates based on lessons learned from completed TRAs • Incorporation of “working draft” appendices on TRL 7 calculator, and Process Control / Software TRAs Changes are not tracked.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
BCP	Baseline Change Proposal
CD	Critical Decision
CTE	Critical Technology Element
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EM	U.S. Department of Energy's Office of Environmental Management
EM CPOT	EM Cognizant Program Office for TRAs
ETR	External Technical Review
FPD	Federal Project Director
FPL	Federal Program Lead
G	Guide
ICR	Independent Cost Review
IPR	Independent Project Review
IPT	Integrated Project Team
LOI	Lines of Inquiry
M	Manufacturing and quality
M&S	Modeling and Simulation
NASA	U.S. National Aeronautics and Space Administration
NNSA	National Nuclear Security Administration
O	Order
ORR	Operational Readiness Review
P	Programmatic, customer focus, documentation
PDSA	Preliminary Documented Safety Analysis
POA	Plan of Action
R&D	Research and Development
RAMI	Reliability, Availability, Maintainability, Inspectability
S&T	Science and Technology
STD	Standard
SOPP	Standing Operating Policies and Procedures
T	Technology, technical aspects
TE	Technology Element
TMP	Technology Maturation Plan
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TSR	Technical Safety Requirements
WPS	Waste Processing System

1.0 INTRODUCTION

This Guide is the U.S. Department of Energy's Office of Environmental Management's (EM's) program guidance for implementing Technology Readiness Assessment (TRA)/ Technology Maturation Plans (TMP) guidance in Department of Energy (DOE) Guide 413.3-4, *Technology Readiness Assessment Guide*. DOE Guide 413.3-4A provides suggested guidance to DOE and National Nuclear Security Administration (NNSA) program offices on conducting TRAs, developing TMPs and developing program specific guidance. This EM Guide is for use by all EM elements.[1] Guides are not requirements documents, and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.

EM began piloting its TRA/TMP process in 2006. The initial version of the *EM Technology Readiness Assessment (TRA*)/*Technology Maturation Plan (TMP) Process Guide* was published in March 2008. Lessons learned from the conduct of seven TRAs completed since March 2008 have been incorporated in this revision.

This Guide is written to support the conduct of a TRA by an independent team, as well as the development of a plan to mature the technologies, the TMP, which is completed by the project/program. Projects and programs may also use this guide to assist them in performing a self-assessment of their technology readiness and then develop plans to mature technologies, and manage and control technology development and deployment.

It is recommended that projects/programs use this Guide to conduct a self-assessment of the technology readiness and develop an initial TMP prior to an independent TRA. This approach improves the overall efficiency of the TRA process, while providing a basis for management and control of the technology development and deployment activities conducted by the project/program. Revisions to the TMP may be required as a result of the independent TRA.

The user of this Guide is cautioned in using only the technology readiness level metric as the single criterion for deciding between competing alternatives. The bases for the decision should include the degree of difficulty to mature the technology alternatives to the desired level, including consideration of risks, cost, and schedule associated with the technology maturation process.

Projects/programs with existing TMPs should consider updating the TMP to the guidance in this revision of the Guide after their next TRA.

This Guide is intended to be a "living document" and will be modified periodically as lessons learned from implementing the TRA/TMP processes are identified.

[1] EM Standing Operating Policies and Procedures (SOPP) #27, Technical Readiness Assessments/Technology Maturation Planning.

2.0 OVERVIEW OF TECHNOLOGY READINESS ASSESSMENTS AND TECHNOLOGY MATURATION PLANS

This implementation Guide has been developed based on experience with tank waste and nuclear material processing systems or similar types of technology development and implementation activities. The TRA process in this Guide is applicable to all EM elements including Mission Unit functional areas such as soils and groundwater, and field offices. Modifications to the TRA process guidance necessary to conducte the TRA of the program under evaluation should be documented during the planning process for the TRA.

As part of the continuous improvement process, changes to the definitions and criteria, including approaches for assessing different types of technology systems such as software systems and late stage technology assessments (i.e., Technology Readiness Level (TRL) 7 through TRL 9), will be implemented in stages. The first stage will be to develop the draft assessment tools (i.e., TRL calculator criteria, checklists, etc.), and then the tools will be piloted during an appropriate technology assessment. Lessons learned will be applied to refine the tools. Finally, TRL calculators/tools will be incorporated in this Guide such that they can be applied to EM projects/programs in a consistent manner. This revision of the Guide includes "working draft" appendices of the TRL 7 calculator and guidance for conducting software TRA. These appendices are included here for information. TRA teams are encouraged to use and provide feedback to the EM office responsible for this guide. After these guides are piloted during appropriate technology assessments, they will be updated and fully incorporated in the guide.

2.1 Objectives of TRAs and TMPs

In accordance with DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, TRAs and TMPs are required for Major Systems Projects (i.e., those with total project cost greater than $750M) prior to Critical Decision (CD) 2. However, they are also highly recommended for smaller projects, as well as Operations Activities, such as technology demonstrations, which involve the development and implementation of new technologies or technologies in new operational environments. Operations Activities are EM's non-capital asset activities that adhere to many of the same management principles as projects.

Results of TRAs provide a snapshot in time of the maturity of technologies and their readiness for insertion into the design process and execution schedule for projects or Operations Activities. TMPs detail the steps necessary for developing technologies that are less mature than desired to the point where they are ready for project insertion. TRAs and TMPs are effective management tools for reducing technical risk and the potential for technology driven cost increases and schedule delays.

2.2 The TRA

The TRA is a systematic, metric-based assessment of how far technology development has progressed. It is not a pass/fail exercise, and is not intended to provide a value judgment of the technology developers or the technology development program. A TRA can:

- Identify the gaps in testing, demonstration and knowledge of a technology's current readiness level and the information and steps needed to reach the readiness level required for successful inclusion in the project;
- Identify at-risk technologies that need increased management attention or additional resources for technology development; and
- Increase the transparency of management decisions by identifying key technologies that have been demonstrated at certain levels of maturity or by highlighting immature or unproven technologies that might result in increased project risk.

A TRA evaluates technology maturity using the TRL scale that was pioneered by the National Aeronautics and Space Administration (NASA) in the 1980s. A TRL indicates the maturity of a given technology according to the definitions and descriptions in Table 1 (Note: these may require modification for non-waste processing applications, see section 3.4.1). TRLs provide a common language and measurement scale to enhance communication within and between the science and technology and project/program communities, both in government and industry. Figure 1 provides a schematic of the meaning of the TRLs in the context of EM projects and Operations Activities. The TRL scale ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations).

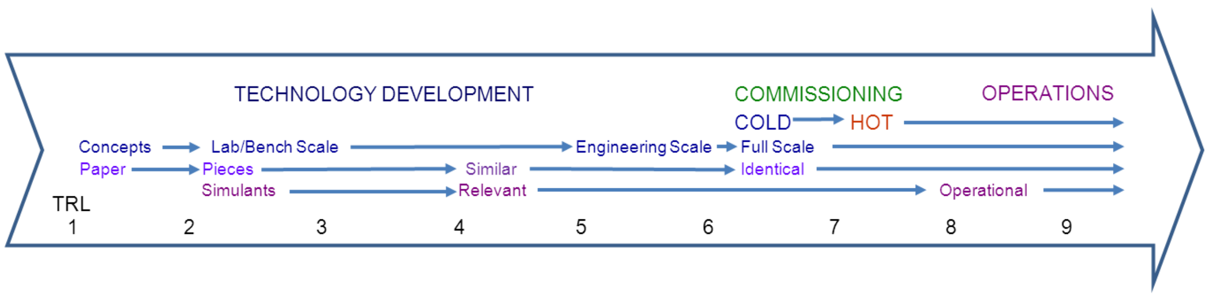


Figure 1 Schematic of DOE Technology Readiness Levels

Caution

TRLs should not be used as a basis for comparing competing technologies. A TRL, by itself, does not give an indication of the difficulty to advance the maturity of the technology, that is the risks, scope, schedule, and costs associated with developing a technology to desired levels of maturity. A technology judged to have a relatively low TRL (e.g., 3) may be easier and less costly to develop to TRL 6 than a technology with a higher TRL (e.g., 5).

Table 1 Technology Readiness Levels

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	**TRL 9**	Actual system operated over the full range of expected conditions.	Actual operation of the technology in its final form, under the full range of operating conditions. Examples include using the actual system with the full range of real wastes.
System Commissioning	**TRL 8**	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with real waste in hot commissioning.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in a relevant environment	Prototype[a] full scale system. Represents a major step up from TRL 6, requiring demonstration of a system prototype in a relevant environment. Examples include testing the prototype in the field with a range of simulants and/or real waste and cold commissioning.
Technology Demonstration	**TRL 6**	Engineering scale, similar (prototypical) system validation in a relevant environment	Representative engineering scale system, which is well beyond the scale tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness and system integration. Examples include testing a prototype with real waste and a range of simulants.
Technology Development	**TRL 5**	Laboratory/bench scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity system in a simulated environment and/or with a range of real wastes and simulants.
	TRL 4	Component and/or system validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in a laboratory and testing with a range of simulants.[b] Laboratory/bench scale testing may not be appropriate for all systems. For example, mechanical systems, such as robotic retrieval technologies, may require full scale prototype testing to meet TRL 4.
Research to Prove Feasibility	**TRL 3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory/bench scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. Components may be tested with simulants. For some applications, such as mechanical systems, this may include computer and/or physical modeling to demonstrate functionality.
Research to Prove Feasibility / **Basic Technology Research**	**TRL 2**	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.
Basic Technology Research	**TRL 1**	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.

[a] A prototype is defined as a physical or virtual model used to evaluate the technical or manufacturing feasibility or utility of a particular technology or process, concept, end item, or system.
[b] If feasible, it is recommended to include tests on a limited range of real waste prior to achieving TRL 4.

A TRL is not an indication of the quality of technology implementation in the design. However, technology testing results are critical in determining the TRL. Testing should be conducted in the proper environment and the technology tested should be of an appropriate scale and fidelity. TRL definitions regarding testing “scale,” “system fidelity,” and “environment” are provided in Tables 2 and 3.

Table 2 TRL Scale, Fidelity, and Environment Definitions

Scale	
Full Plant Scale	Matches final application
Engineering Scale[1]	Typically (1/10 < system < Full Scale)
Laboratory/Bench[1]	Typically < 1/10 Full Scale
[1] The Engineering Scale and Laboratory/Bench scale may vary based on engineering judgment.	
System Fidelity	
Identical System Configuration	Matches final application in all respects
Similar Systems Configuration	Matches final application in almost all respects
Pieces	System matches a piece or pieces of the final application
Paper	System exists on paper (i.e., no hardware system)
Environment (Waste)	
Operational (Full Range)	Full range of actual waste
Operational (Limited Range)	Limited range of actual waste
Relevant	Simulants plus a limited range of actual wastes[2]
Simulated	Range of simulants
[2] Simulants should bound relevant physical and chemical properties. Testing should be conducted with as wide a range of actual waste as practicable, consistent with waste availability, safety, As Low As Reasonably Achievable (ALARA), cost, and project risk.	

Table 3 TRL Testing Definitions

TRL Level	Scale of Testing	Fidelity	Environment[1,2]
9	Full	Identical	Operational (Full Range)
8	Full	Identical	Operational (Limited Range)
7	Full	Similar	Relevant
6	Engineering	Similar	Relevant
5	Laboratory/Bench	Similar	Relevant
4	Laboratory/Bench	Pieces	Simulated[3]
3	Laboratory/Bench	Pieces	Simulated
2		Paper	
1		Paper	

[1] Simulants should match relevant physical and chemical properties
[2] Testing should be conducted with as wide a range of actual waste as practicable; and consistent with waste availability, safety, ALARA, cost, and project risk
[3] If feasible, it is recommended to include tests on a limited range of real waste tests.

The range and type of EM projects that may undergo a TRA represent a diverse range of technologies and level of complexity. Table 4 provides examples of how technologies may progress in maturity[2]. See TRL Calculators in Attachment H for the full listing of attributes.

Table 4 Examples of TRL Stages

TRL	Low Activity Waste (LAW) Vitrification	Advanced Neutron Absorber (ANA) Development
9	• Hot operations of the LAW plant	• DOE Spent Nuclear Fuel (SNF) packaged with ANA accepted at geologic repository for disposal
8	• Hot commissioning of the LAW plant	• Nuclear Regulatory Commission issues licenses for spent fuel storage, transportation, and disposal systems using ANA
7	• Cold commissioning of the LAW plant	• Manufacturing of commercial size ingots (10k lb) demonstrated including ingot reduction to plate • Full size SNF baskets using ANA are fabricated • American Society for Testing and Materials (ASTM) grants final material specification • American Society of Mechanical Engineers grants code case for use in welded structural applications
6	• Operation of a one-third scale LAW melter system using simulants • Continued glass formulation development using crucible and small-scale melter testing of actual waste and simulants	• Manufacturing of 3000 pound ingots demonstrated including ingot reduction to plate
5	• Development and laboratory/bench scale testing of melter systems including feed and off gas systems • Crucible testing using actual wastes • Continued glass formulation development to optimize glass properties and performance	• Investigations into scale-up from 300 pound ingots completed. • Secondary melt process parameters determined
4	• Waste characterization continues • Small-scale testing of melter technologies and systems • Continued glass formulation testing to determine potential glass compositions, waste loadings, and durability while maintaining acceptable properties	• Manufacturing of 300 pound ingots demonstrated including ingot reduction to plate • ASTM grants provisional material specification
3	• Waste characterization continues • Crucible size tests to determine potential glass formulations for immobilizing LAW • Determination of glass properties needed for successful processing and performance • Investigation of melter technologies	• Button-size ingots prepared • Manufacturing of 50 pound ingots demonstrated including ingot reduction to plate • Material property characterization including welded specimens
2	• Investigation of the structure, durability, and ability of glass to incorporate a variety of elements • Waste characterization begins	• Thermodynamic modeling of melt chemistry completed • Microstructural characterization
1	• Fundamental investigations of glass chemistry and structure	

[2] The examples in Table 4 are not meant to be characteristics for measuring contractual performance, nor do they necessarily represent an actual account of project history or progress.

Table 4 Examples of TRL Stages (continued)

<table>
<tr><th>TRL</th><th>Removal of Cesium from High Level Waste (HLW) Salts</th><th>Adjustment of Aquifer pH</th></tr>
<tr><td>9</td><td>• Completion of one year of SWPF operations with a variety of feeds</td><td>• Deployment of base injection at gates in funnel-and-gate system</td></tr>
<tr><td>8</td><td>• Installation of technologies in SWPF
• SWPF start-up and commissioning testing</td><td rowspan="2">• Base injection skid built
• Additional reaction path modeling to finalize design of base solution
• Final base solution field injection test</td></tr>
<tr><td>7</td><td>• Continued modular CSSX system demonstration of flowsheet and operations
• Full scale Salt Waste Processing Facility (SWPF) tests with simulants</td></tr>
<tr><td>6</td><td>• Integrated scaled contactor testing
• Modular CSSX system operational, processing real waste from tanks (operations of Actinide Removal Process/Modular Caustic Side Solvent Extraction Unit)</td><td>• Initial engineering prototype field test; injection of sodium hydroxide and trisodium phosphate solutions in side-by-side plots</td></tr>
<tr><td>5</td><td>• Laboratory/bench scale testing of CSSX with real waste
• Intermediate-diameter contactor testing</td><td rowspan="3">• Batch titrations in lab
• Column studies of different bases</td></tr>
<tr><td>4</td><td>• Laboratory maturation of the technology toward overcoming HLW salt challenges
• Small diameter contactor testing
• Solvent-liquid phase separation optimization</td></tr>
<tr><td>3</td><td>• Demonstration of caustic-side solvent extraction (CSSX) at laboratory/bench scale
• Initiate work to determine solvent and stripping agent</td></tr>
<tr><td>2</td><td>• Synthesis of tailored host molecules, such as crown ethers and calixarenes that selectively bind cesium</td><td>• Reaction path models used to develop concept and design</td></tr>
<tr><td>1</td><td>• Fundamental investigations on the structural and thermodynamic principles of host-guest chemistry</td><td>• Fundamental chemical reactions of base injected into subsurface modeled</td></tr>
</table>

2.3 The Technology Maturation Plan

The TMP is a planning document that lays out the activities required to bring immature Critical Technology Elements (CTEs) up to the desired TRL. A technology element is "critical" if the systems being acquired depend on the technology element to meet operational requirements and if the technology element or its application is either new or novel. The TMP includes preliminary schedules and rough order of magnitude cost estimates that allow decision makers to determine the future course of technology development. Normally the TMP will be followed by detailed test plans that provide more accurate cost and schedule information that can be incorporated into the project baseline. See Section 4.0 for more information on the TMP.

2.4 The Relationship of TRAs and TMPs to DOE CDs

DOE Guide 413.3-4A and EM recommend conducting TRAs during conceptual design and preliminary design processes; at least 90 days prior to CD milestones. Figure 2 shows how TRAs and other key reviews support each of the CDs. The TRA/TMP process serves as one of the tools employed to help evaluate development progress and obtain CD approval. There are numerous additional requirements for each CD, see DOE O 413.3B.

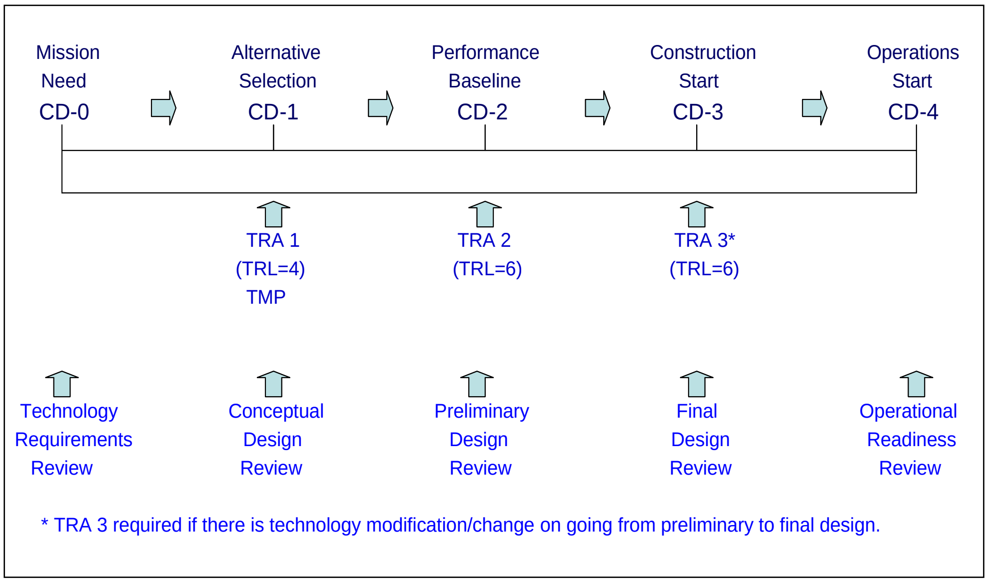


Figure 2 Suggested Technology Readiness Assessments and Other Reviews for Critical Decisions

Small projects and Operations Activities have phases and reviews similar to those depicted in Figure 2. TRAs and TMPs are not typically required for these smaller projects and Operations Activities, but are considered a good management practice, and highly recommended.

DOE has adopted TRL 6 as the maturity level normally necessary before a technology can be incorporated into final design which correlates to CD-2. EM has designated TRLs 7, 8, and 9 as levels associated with cold commissioning, hot commissioning, and hot operations, respectively. Prior to start of operations, start-up testing and operational readiness reviews should ensure that the CTEs have advanced to the target maturity (TRL 6 toward TRL 9), as applicable and appropriate. Many of the aspects related to technical maturity are assessed as part of these reviews. TRL calculator tables, or a similar tool, for these late stage maturity levels have yet to be developed for EM cleanup projects. They are planned to be developed and piloted during upcoming reviews, and then incorporated into the next revision of this Guide. Until that time, the Federal Project Director (FPD), or the Federal Program Lead (FPL) for an Operations Activity[3], is responsible for ensuring planned turnover, startup and readiness reviews address technology maturity aspects to ensure the system is ready to transition to hot operations. Appendix 1 is a “working draft” of the TRL 7 calculator table.

[3] The FPL for an Operations Activity is also referred to as the Operations Activity Manager in other EM documents.

CDs are defined in DOE Order 413.3B. The correlation between technology maturation and reviews with project/program phases is described below. Although the following discussion is in the context of a Major System Project the phases represented by the various CDs are readily correlated to similar stages within a smaller project or Operations Activity. These descriptions assume that all other requirements prescribed by DOE Order 413.3B, such as safety and quality, are integrated with the TRA process, as appropriate.

<u>CD-0, Approve Mission Need -</u> There is a need that cannot be met through other than material means: identification of a mission-related need and translation of this gap into functional requirements for filling the need. *The mission need is independent of a particular solution and should not be defined by equipment, facility, technological solution, or physical end item* (413.3B). The focus for Technology Assessment, at this stage, is on clear statement of the requirements of the input and the desired output of the process. For waste processing, this would include characterization of the waste as well as definition of requirements for the processing and the waste form. A technology assessment should be performed to assess the adequacy of requirements definition and characterization information in support of the Mission Need Statement, and to determine if any additional work is necessary. If additional work is necessary to adequately define technical scope of the project, a detailed plan with a proposed schedule should be developed.

<u>CD-1, Approve Alternative Selection and Cost Range -</u> The selected alternative and approach are the optimum solution: identification of the preferred technological alternative, preparation of a conceptual design, and development of initial cost estimates. A TRA and a TMP should be performed during conceptual design to support the CD-1 approval process. A TRA/TMP supporting CD-1 may be used to (a) assess the relative maturity and maturation requirements of competing technologies and provide a basis for input into the selection amongst them; and/or (b) assess the maturity and maturation requirements of the selected technology. Prior to CD-1 approval, all CTEs of the design should have reached TRL 4 and a TMP that details the strategies for bringing all CTEs to TRL 6 should have been prepared. If a technology is assessed at less than TRL 4, then the degree of difficulty to mature the technology, the risk to the project, and the rationale for proceeding with a CTE(s) with a lower TRL(s) should be identified to the Approval Authority as part of the CD-1 approval process.

<u>CD-2, Approve Performance Baseline -</u> Definitive scope, schedule, and cost baselines have been developed: completion of preliminary design, development of a performance baseline that contains a detailed scope, schedule, and cost estimate. The process of technology development, in accordance with the approved TMP, should support all CTEs reaching TRL 6. Attainment of TRL 6 indicates that the technology is ready for insertion into final design. Proceeding beyond CD-2 with a TRL of less than 6 is not recommended. If a technology is assessed at less than TRL 6, then the TMP and rationale for proceeding with a CTE(s) with a lower TRL(s) should be specifically briefed to the Approval Authority as part of the CD-2 approval process. For Operating Activities and small projects the site and program office sponsors serve as the approval authorities. The decision to proceed with a TRL of less than 6 should consider the degree of difficulty to advance the technology to the desired TRL, with specific focus on risks, cost, and schedule impacts.

<u>CD-3, Approve Start of Construction/Execution -</u> The project is ready for implementation: completion of essentially all design and engineering and beginning of construction, implementation, procurement, or fabrication. A TRA is required if there is significant CTE modification occurs subsequent to CD-2 as detailed design work progresses. A significant CTE modification could include a change in the technology or the need for additional support systems. If significant modification of a technology occurs, the TRA should be performed and a focused TMP developed to ensure that the modified technology has attained TRL 6 prior to authorization to begin construction.

<u>CD-4, Approve Start of Operations or Project Completion -</u> The project is ready for turnover or transition to operations, if applicable: readiness to operate and/or maintain the system, facility, or capability. Successful completion of an Operational Readiness Review (ORR) corresponds to maturing the CTEs from TRL 6 through TRL 9. The activities leading to CD-4 include various types of readiness reviews and assessments, such as the system operability testing, culminating in the ORR. Specific TRL calculator tables, or similar tools, have yet to be developed for these late stage maturity levels. They will be developed, piloted, and incorporated into the next revision of this Guide. Until such time, the FPD/FPL is responsible for ensuring planned reviews address technology maturity aspects to ensure the system is ready to transition to hot operations. Appendix 1 is a "working draft" of the TRL 7 calculator table.

2.5 The Relationship of TRAs and TMPs to Other Reviews

DOE conducts many peer reviews of projects and programs. Examples of these reviews include Independent Project Reviews (IPRs), External Independent Reviews (EIRs), Independent Cost Reviews (ICRs), and EM's External Technical Reviews (ETRs) and Construction Project Reviews. (See DOE Guide 413.3-9 for guidance on project reviews)

EM has issued guidance for the conduct of ETRs; as described in *U.S. Department of Energy Office of Environmental Management External Technical Review (ETR) Process Guide*, September 2008:

> "The purpose of an ETR is to reduce technical risk and uncertainty. ETRs provide pertinent information for EM to assess technical risk associated with projects and develop strategies for reducing the technical risk, and provide technical information needed to support critical project decisions. Technical risk reduction increases the probability of successful implementation of technical scope. In general, an ETR assesses technical bases, technology development, and technical risk identification and handling strategies."

The purpose of IPRs is given in DOE Order 413.3B. They are one of the measures that can be taken to ensure the timely resolution of engineering, system integration, technology readiness assessments, design, quality assurance, operations, and maintenance and nuclear/ non-nuclear safety issues. An IPR assists in reducing technical risk and uncertainty which increases the probability of successful implementation of technical scope including new technologies. EM's Construction Project Reviews are an IPR type.

The use of these review processes could overlap. In general, it is anticipated that TRAs, and the associated TMPs, will be focused on the development status of technologies; ETRs, on the other hand are likely to be used for reducing the risk and/or uncertainty associated with a particular technical issue. In some cases, an ETR may include lines of inquiry specifically focused on technology readiness and maturation. A TRA may also be part of an EM Construction Project Review to provide analysis on the status of technology development. If there is uncertainty as to which process to use, the EM Cognizant Program Office for TRAs (CPOT) should be consulted. The EM CPOT[4] is the office responsible for the TRA process, the conduct of TRAs, and this Guide.

Appendix 1 provides guidance on the integration of TRAs with the turnover and readiness assessments at the end of a project or operating activity.

2.6 The Relationship of TRAs and TMPs to Risk Management

The TRA should not be considered a formal *risk* assessment, but it should be viewed as a tool for assessing project/program risks associated with implementation of a new technology and specifically the adequacy of technology maturation planning by the project/program. Critical technologies and other potential technology risk areas that may need the attention of the FPD, or FPL for applicable Operations Activities, are highlighted by the TRA and captured in the TMP. Figure 3 illustrates the relationship of TRAs and TMPs to risk management. Technology readiness risk is only one component of risk.

A TRL of 6 for the individual CTEs in a system does not equate to the elimination of the technical risks associated with those technologies. The assessment of each CTE addresses the maturity of the associated technology. Missing is the risks associated with the integration of those CTEs to each other, to other elements of the system, and to elements external to the system. EM has developed a set of TRL calculator tables to evaluate the integration of the total system to assist in reducing the technical risks associated with integration. These integration tables are focused at TRLs 4 and 6, and EM relies on system operability and start-up testing and assessments for risk reduction post TRL 6.

[4] The term "CPOT" is introduced as a generic descriptor to mitigate the need for future revisions to this Guide due to reorganizations that may occur within EM. As of the release of revision 1 of this Guide, the EM CPOT is the Office of Tank Waste Management (EM-21). Refer to SOPP 27 for current organizational responsibilities for execution of the TRA and TMP processes.

The TRA assesses the level of technology maturity and feeds into a TMP that contains an assessment of difficulty to mature the technology, i.e., the scope, cost, and schedule of developing project technologies to the desired level of maturity. The TMP along with technology risk mitigation strategies are used to develop a plan to manage technology risk. Technology risk is then considered along with other project risks to develop strategies to manage overall project risk. The results of the TRA and the TMP may also be inputs into project plans for the management and control of engineering and technology development and deployment.

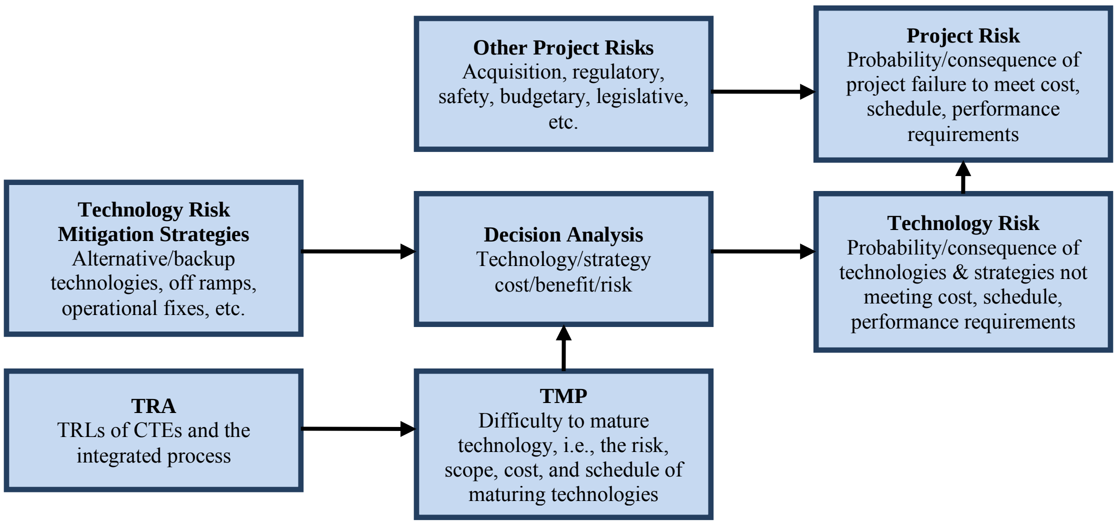
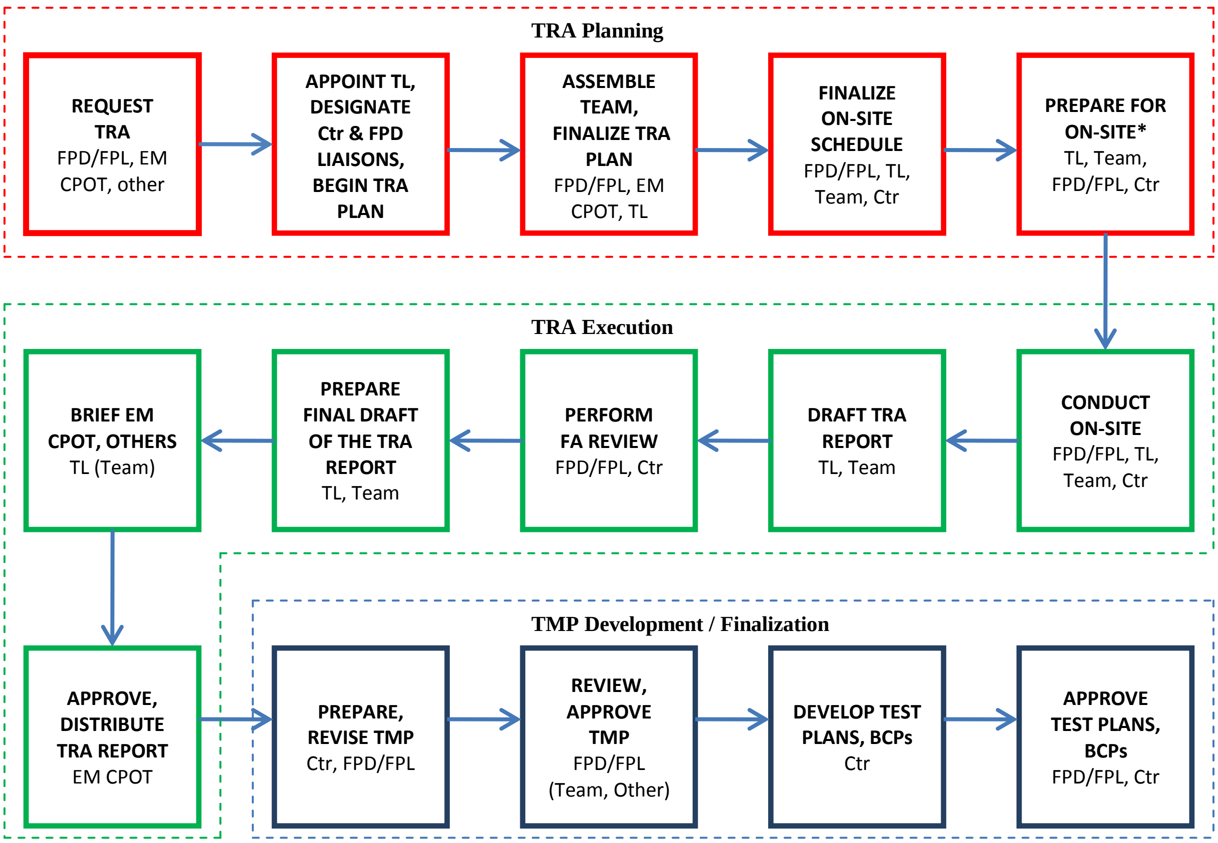


Figure 3 TRAs, TMPs, Technology, and Risk Management

3.0 TECHNOLOGY READINESS ASSESSMENT PROCESS

3.1 Process Overview

The TRA/TMP process is depicted in Figure 4. The TRA/TMP process is divided into three stages: assessment planning, assessment execution, and TMP preparation. Detailed guidance is provided in Sections 3.4, 3.5, and 4.0.



Key for undefined acronyms in figure: Ctr = Contractor, TL = TRA Team Leader, Team = TRA Team, FA = Factual Accuracy, BCP = Baseline Change Proposal
* If a self-assessment TRA was performed and a TMP developed, these documents should be input to the preparation for the on-site assessment.

Figure 4 TRA/TMP Process

The TRA Planning Stage (Section 3.4) begins when it is determined by the FPD/FPL, or EM program office that sponsors the project/program, or EM CPOT that a TRA is required. Assessment planning involves selection of the TRA team, development of a TRA Plan, and review of critical documents. The TRA Planning Stage ensures pertinent information required to successfully perform the TRA is documented and readily available to the TRA team.

The TRA Execution Stage (Section 3.5) begins with the on-site assessment activities. Assessment activities involve identification and evaluation of CTEs, determination of TRLs, TRA reporting, and a close-out briefing. This stage ensures appropriate data are gathered, appropriate elements are assessed, and assessment results are adequately documented.

The TMP Development/Finalization Stage (Section 4.0) may begin after the factual accuracy review is conducted or after the TRA Report is approved. If an initial TMP was drafted by the project/program, it may require revision and finalization based on the results and recommendations of the TRA. Otherwise, the TRA will provide the basis for developing the TMP. The TMP ensures the actions required to develop the technologies to the required levels are documented.

A typical timeline for a TRA is provided in Table 5. A typical timeline for a TMP is provided in Table 6. However, the timing for each of these will vary considerably based on the complexity of the project.

Table 5 Typical TRA Timeline

Activity	Typical Time Frame
TRA Requested	Time 0
Team Leader Chosen, TRA Plan Begun, Federal Project/Program & Contractor Liaisons Designated	Week 0 - 2
Team Assembled, TRA Plan Finalized	Week 2 - 6
On-Site Assessment Schedule Finalized, Critical Documents Distributed to TRA Team	Week 6 - 9
On-Site Assessment	Week 9 - 13
Draft TRA Report Issued for Factual Accuracy Review	Week 13 - 17
Factual Accuracy Review Completed	Week 17 - 18
Briefings Completed, Final TRA Report Issued	Week 18 - 21

Table 6 Typical TMP Timeline

Activity	Typical Time Frame
Begin TMP	Time 0
Draft TMP Completed	Week 0 - 6
Review TMP	Week 6 - 8
TMP Approved	Week 8 - 10
Test Plans Developed	Week 10 - 16
Test Plans Approved and as required Change Package Approved	Week 16 - 20
Incorporate Test Plans Into Baseline	Project Dependent

3.2 Key Roles and Responsibilities

3.2.1 EM Program Office

(i.e., the EM organization that sponsors the project/program to be reviewed)

1. May request a TRA.
2. Approves TRA Plans for TRAs it requests.

3.2.2 EM Cognizant Program Office for TRAs

1. Owns the TRA/TMP process and this Guide.
2. May request a TRA.
3. Provides input to the development of TRA Plans, and approves TRA Plans.
4. Identifies and appoints the TRA Team Leader and the TRA Team; may appoint a TRA Facilitator to assist the TRA Team Leader.
5. If necessary, provides training to TRA team members on the TRA/TMP process.
6. Reviews, approves, publishes, and distributes TRA Reports.

3.2.3 Federal Project Director (or Operations Activity Federal Program Lead)

1. May request a TRA. If the project is a Major Systems Project, then the FPD shall request a TRA prior to CD-2.
2. Designates a Federal Project/Program Liaison.
3. Provides input to the development of TRA Plans.
4. Approves TRA Plan.
5. Requests assignment of Contractor Liaison.
6. Performs factual accuracy review of draft TRA Report.
7. Reviews and approves TMP and change packages.
8. Incorporates TMP details into project risk management plan and baseline.
9. Includes integrated project team members in the review of the TRA report and TMP.

3.2.4 Federal Project/Program Liaison

1. Serves as the primary project/program interface with the TRA Team. Works closely with the TRA Team Leader and Contractor Liaison to coordinate the TRA.
2. Reviews and approves the list of reference documents to be provided to the TRA team to ensure completeness and absence of bias.
3. Distributes documents assembled by the Contractor Liaison to the TRA Team.
4. Ensures compliance with TRA Team security, badging, and training requirements.
5. Ensures that all TRA facility, resource, and logistics requirements are met.
6. Conducts TRA Kick-Off Meeting jointly with TRA Team Leader.
7. Provides administrative and technical editing support to the TRA Team as needed.
8. Coordinates the factual accuracy review of the draft TRA Report.

3.2.5 Contractor

(i.e., the contractor executing the project/program to be reviewed)

1. Assigns a Contractor Liaison.
2. Provides technology information to the TRA Team in the form of tours, briefings, documents, and test information.
3. Performs factual accuracy review of the draft TRA Report.
4. Prepares the TMP.
5. Prepares detailed test plans and change packages that implement the TMP.
6. Approves and implements test plans.

3.2.6 Contractor Liaison

1. Serves as the primary Contractor interface with the TRA Team. Works closely with the TRA Team Leader and Federal Project/Program Liaison to coordinate all areas of the TRA.
2. Compiles and distributes a listing of technology elements to the TRA Team.
3. Serves as the conduit for communication between the TRA Team and Contractor.
4. Coordinates with the TRA Team Leader and Federal Project/Program Liaison on arrangements, facilities, and resources at the site for the assessment.
5. Coordinates briefings and tours of site facilities for the TRA Team as applicable.
6. Coordinates the Contractor factual accuracy review of the draft TRA Report.

3.2.7 TRA Team Leader

1. Serves as the TRA Team primary point of contact.
2. Reviews TRA Team members' qualifications to ensure that the team has the appropriate expertise and abilities to execute the TRA.
3. Develops the TRA Plan with input from the EM CPOT and FPD/FPL.
4. Develops the on-site assessment schedule with input from the TRA Team, FPD/ FPL, Contractor, and the EM CPOT.
5. Develops TRA schedule with input from EM CPOT and team members.
6. Is accessible during the entire review process, and actively leads completion of the requirements of the TRA Plan. This commitment includes development of written input, and leadership of team meetings.
7. Organizes the TRA Team's work and makes assignments so that time on-site is well spent and provides the required products.
8. Reviews the TRA request to assure that specific topics or emphasis requested are properly understood and identified in the TRA Plan. Obtains clarification from the Requester as needed.
9. Coordinates arrangements and agenda for the TRA with the federal and contractor liaisons.
10. Coordinates TRA Team requests for additional information during review of materials provided in advance; communicates these requests to the Federal Liaison; obtains agreement on time for responses to requests.
11. Conducts TRA Team conference calls as needed prior to and after the on-site assessment.
12. Coordinates TRA Team's arrival at the site of the assessment. Identifies required check-in at site security office and time and place for initial meeting with project/program officials.
13. Presents initial briefing describing review team charge and TRA process to on-site assessment project/program participants.
14. Participates as a subject-matter-expert for assigned technology areas.
15. Establishes TRA Team responsibilities and timelines for completion of detailed write-ups supporting assessment results.
16. With TRA Team support, conducts and provides copies of the exit brief for on-site assessment project/program participants.
17. Assembles and edits drafts of the TRA Report and all briefings.
18. Reviews and consolidates TRA Team comments to ensure consistency throughout the report.
19. Provides a draft copy of the report to the TRA Team for consensus on the content and

to the FPD/FPL and Contractor for factual accuracy review.

20. As the final authority on the report content: implements comment resolution as appropriate. Since a significant level of effort may be required to incorporate comments, the TRA Team members may be tasked to rewrite sections.
21. Approves the final report and submits to EM CPOT.
22. Briefs EM CPOT and other interested parties on the final report.
23. Is available for post TRA consultation.

3.2.8 TRA Team Members

1. Serve as subject matter experts in technical areas relevant to the technology under review. TRA Team members should be independent from the entities responsible for decision-making and implementation of the technology being reviewed. Specifically, they should not be individuals who are from offices assigned direct line management responsibility for the work being reviewed.
2. Objectively assess technologies, determine TRLs, and document associated bases for the TRL determinations.
3. Review all materials provided prior to the on-site assessment and advise the TRA Team Leader if additional information is needed.
4. Finalize listing of CTEs to be assessed.
5. Participate in all TRA Team conference calls.
6. Be willing and capable of staying on-site during assessment execution, and to actively participate in the process described in the TRA Plan.
7. Submit draft input in accordance with this guidance.
8. Prepare questions resulting from review of material received prior to on-site assessment and provide to the TRA Team Leader in advance.
9. Review draft report to assure determinations are accurately described and to identify possible conflicts.
10. Ensure availability for follow-up consultations.

3.3 TRA Team Independence

Independence of the TRA Team (leader and members) is a key for conducting TRAs. As a minimum, the TRA Team Leader and TRA Team members should be independent from the project team implementing the technical scope; the TRA Team Leader should not be from the organization responsible for the implementation of the technology being assessed. For example, TRA Team members should not be DOE employees or contractors affiliated with the project (or competing projects) to be reviewed. At the discretion of the CPOT and/or FPD/FPL, team members may be requested to sign Conflict of Interest forms documenting their independence.

Any exceptions to the guidelines for TRA Team independence require approval by the EM CPOT.

3.4 TRA Planning Stage

The TRA Planning Stage should begin at the initiation of a project or Operations Activity to ensure the TRAs are effective and timely. Experience has shown that the most successful and beneficial TRAs are those in which the TRA concept has been inculcated into an applicable project or program from inception, generally the start of the conceptual design phase. In general, the best approach is for the project/program team to conduct a self-assessment by taking the initial steps to identify CTEs, conduct TRL determinations, and develop a TMP. Then, in a collaborative process, the TRA Team will work with the project/ program team to review, validate, and/or provide recommendations to improve these initial efforts to reduce risk, mitigate unforeseen challenges, and ensure success for the activity.

The steps in planning a TRA are summarized below. These steps are shown in the TRA/ TMP Process Diagram in Figure 4. Additional information regarding the major steps is provided in the sections that follow.

Request TRA: The FPD/FPL or other EM entities may submit a request for a TRA to the EM CPOT. FPDs of Major System Projects are required to submit a TRA/TMP as part of the package supporting a CD-1 and CD-2 request. TRAs may also be requested for reasons such as support of decision analysis processes, including value engineering studies involving competing technologies, or evaluation of concerns about the viability or maturation state of technologies. The TRA Request should be written and include a brief description of the scope, desired completion date, funding source, and purpose of the request. If possible, requests should be made well in advance to allow the EM CPOT to develop an annual schedule of EM TRAs.

Appoint TRA Team Leader, Designate Federal and Contractor Liaisons, Begin Writing the TRA Plan: The EM CPOT approves the request for the TRA and, with the help and approval of the Requester and the EM program office that sponsors the project/program, appoints a TRA Team Leader. The EM CPOT may also appoint a Facilitator, experienced in the TRA process, to support the TRA Team Leader. The TRA Team Leader, with input from the EM CPOT and the FPD/FPL, begins work on the TRA Plan that outlines how the review will be conducted. The TRA Plan contains the elements detailed in Section 3.4.1 and in Attachment A. The FPD/FPL and the Contractor each designate liaisons to serve as primary contacts with the TRA Team. The FPD/FPL should consider members of the integrated project team as potential candidates for the liaison role.

Assemble the TRA Team and Finalize the TRA Plan: The TRA Team Leader finalizes the TRA Plan and submits it for approval of the EM CPOT, the FPD/FPL, EM program office responsible for the project/program being reviewed, and the Requester. The EM CPOT with the help of the Requester and the TRA Team Leader assemble the TRA Team. The members of the team should have expertise in the areas under review and be independent from the project/program. Members of the team may come from other DOE programs, other federal agencies, national laboratories, academia or industry. If a TRA or ETR has previously been conducted on the project/program, it is beneficial to include some of the individuals that conducted those reviews on this TRA. The EM CPOT normally is responsible for supplying funding for, and making the necessary contractual arrangements with, members of the TRA Team; however, this can also be completed by the Requester for unplanned TRAs for which budget has not been allocated with the EM CPOT. The EM CPOT ensures that all contractual arrangements are in place before the TRA proceeds.

Finalize the On-Site Assessment Schedule: The FPD/FPL, the TRA Team, and the Contractor agree on the schedule. The amount of time required for the on-site assessment will vary with the project and the nature of the assessment. Most TRA on-site assessments are 2 to 4 days in duration.

Prepare for the On-Site Assessment: Preparations for the on-site assessment are finalized. The Federal and Contractor liaisons compile a list of reference documents for the technologies to be reviewed and distribute critical documents to the TRA Team. Considerations for the identification and distribution of critical documentation are provided in Section 3.4.2. The TRA Team uses the documents to prepare for the on-site assessment. The TRA Team Leader may also distribute materials such as this Guide to TRA Team members in order to familiarize them with the TRA/TMP process. The TRA Team Leader will usually hold a number of conference calls with the TRA Team to prepare for the on-site assessment. Included in these early conference calls should be the identification of potential CTEs. In addition to reviewing documents, the TRA Team may choose to visit the site to become familiar with the project prior to the on-site assessment.

See Section 3.4.3 for a discussion of TRA on-site facilities, resources, and logistics and Table 7 for implementation tips for TRA planning.

Recommendation

An effective way for the project/program to prepare for the on-site assessment and streamline the TRA Execution Stage is to conduct a self-assessment TRA. The self-assessment should use this Guide to determine CTEs and TRLs. The EM CPOT may be consulted for guidance.

It is especially helpful to have the TRL calculator questions that were completed during the self-assessment available to the TRA Team prior to and during the on-site assessment along with the references that document the responses to the questions.

A self-assessment TRA is also a good tool early in the project to assist the project in developing plans to manage and control technology development and deployment.

3.4.1 TRA Plan

The TRA Team Leader is responsible for developing the Plan, in collaboration with the EM CPOT and FPD/FPL. The Plan is a detailed working plan for conduct of the TRA. Successful implementation of the Plan relies on the TRA Team, EM CPOT, FPD/FPL and the Contractor. Therefore, the TRA Team Leader should actively seek the input of these entities during development of the Plan. The developed Plan is submitted by the TRA Team Leader to the EM CPOT, FPD/FPL, EM program office responsible for the project/program being reviewed, and the Requester for approval. The EM CPOT ensures allocation of required funding.

The TRA Plan:

- Identifies the TRA requester and the reason for the request (e.g., as part of CD-1 submission).
- Identifies the project/program, and the technology (or technologies) being assessed.
- Establishes the scope of the assessment.
- Identifies and provides short resumes for the TRA Team.
- Provides a milestone and deliverables schedule.

While the structure of each TRA Plan is the same, the content is specifically tailored for each project/program. The TRA Plan helps the TRA Team Leader coordinate activities during the assessment.

If the TRL definitions and criteria in this Guide do not fit the project/program, the revised definitions and criteria are included in the TRA Plan. These changes require the approval of the EM CPOT.

See Attachment A for additional information regarding the format of the TRA Plan.

3.4.2 Documentation for Review

An important aspect of planning the TRA is the advanced review of critical documentation. The Federal and Contractor Liaisons are responsible for coordinating the identification and distribution of critical documentation. To the extent possible, the critical documentation should be distributed to TRA Team by the Federal Liaison at least four weeks prior to the scheduled assessment. Submission of the critical documentation is expected to be as an entire package and represent a current state of development.

The critical documentation pertinent to a TRA varies but generally includes: design reports, technology reports, technology bases documents, value engineering studies, technology alternatives studies, relevant regulatory information, and DOE or program reference documents. If the project/program has conducted a self-assessment TRA and developed a TMP, then these documents should be provided to the TRA Team for review. A description of the reference document hierarchy (i.e., a document “roadmap”) is a valuable tool for the TRA Team to assist in and expedite the review process and is highly recommended.

3.4.3 On-site Assessment Facilities, Resources, and Logistics

Prior to the on-site assessment, the TRA Team Leader, and the Federal and Contractor Liaisons, discuss the facilities and equipment needed during the conduct of the TRA. The liaisons ensure that the requested resources are readily available at the start of the on-site assessment. Additional resources identified after the start of on-site activities are communicated to the liaisons by the TRA Team Leader. Liaisons are expected to respond promptly to any requests for additional resources.

Typical considerations regarding on-site assessment facilities, resources, and logistics are:

- Conference Room in un-cleared area or in area accessible to un-cleared TRA Team members with cleared team member escorts, if necessary. The conference room should be equipped with:
  - whiteboard,
  - audio-visual equipment required for presentations,
  - multiple electrical outs,
  - enough space to comfortably accommodate interested personnel, as well as the TRA Team,
  - computer with printing and overhead projection capabilities and Microsoft Word and PowerPoint installed,
  - teleconference capability (If requested by the TRA Team Leader or Liaisons).
- Office space for small group discussions (accessible to un-cleared team members with cleared team member escorts if necessary).
- Security arrangements including:
  - identification of security information and badging for the visit,
  - personnel to conduct classification reviews of documentation used or generated during the review (if the possibility of classified material being part of the TRA),
  - identification of site/project clearance requirements for personnel related equipment such as government and non-government owned laptop computers.
- Required training (i.e., facility access, safety, security, and radiological) for conferencing, office, and project facilities that the TRA Team may visit,
- Personnel skilled in the use of Word and PowerPoint to assist the TRA Team in recording TRA proceedings, especially the CTE and TRL evaluations.
- Allowance in the agenda for breaks, and access to areas for breaks, refreshments, and meals.

Table 7 Implementation Tips for TRA Planning

Planning

- Define the assessment scope clearly and concisely. The definition should describe what is within the scope of the assessment and what is not in the scope of the assessment.
- Critical documentation, including the results of any self-assessment TRA, should be distributed to TRA Team at least four weeks prior to the scheduled assessment.
- Up-front review of documents by the TRA Team will streamline initial meetings (e.g., Kick-Off meeting) by reducing the need for overviews.
- Early in the assessment, address how responses to assessment criteria/questions and the associated bases will be reported and tracked.
- Contact lists including names, addresses, email addresses, phone numbers, and other contact information for the TRA Team and key FPD/FPL and Contractor personnel should be prepared and distributed to all parties. The lists should be prepared early in the process and updated as necessary.
- Establish how the review team will communicate requests to the project/program. It is recommended that the TRA Team Leader be the primary point of interface.

Team Selection

- Team members should be independent of any corporate accountability or responsibilities for managing the technology being assessed.
- Team members should be free of any conflict-of-interest with respect to potential personal benefit due to assessment recommendations. Team members may be requested to sign Conflict of Interest forms documenting their independence.
- The TRA Team Leader should have expertise in the technologies being evaluated, as well as demonstrated ability to lead assessments. Experience in conducting TRAs is preferable but not required. The EM CPOT may appoint an experienced Facilitator to assist the TRA Team Leader.
- Industrial experts (for technologies that are industrial in size), experts from other laboratories with similar technologies, and experts from other DOE and federal programs should be considered.
- Firm commitments from the TRA Team members should be obtained as early as possible.
- Funding and contracting of TRA Team can take considerable time and effort and should begin as early as possible.
- Team size will be dictated by project complexity and size and reviewer expertise.
- There should be at least one TRA Team member with expertise in each major technical area of the project/program.

Team Readiness

- Establish TRA Team communications (status calls, distribution lists, etc.) early in the TRA planning process. The TRA Team Leader may wish to include FPD/FPL and Contractor personnel on some of the calls.

3.5 TRA Execution Stage

The steps in conducting a TRA are summarized below. These steps are illustrated in the TRA/TMP Process Diagram in Figure 4. Additional information regarding the major steps is provided in the sections that follow. Table 8 provides implementation tips for TRA execution.

Conduct the On-Site Assessment: The on-site assessment typically lasts 2-4 days. During this time:

- The TRA Team Leader initiates the assessment by conducting a Kick-Off Meeting. See Section 3.5.1.
- The Contractor provides briefings and conducts tours of applicable site facilities.
- Based on the process descriptions, the TRA Team finalizes the list of CTEs. This may be a review and validation/revision of the CTEs defined during the project/program team's self-assessment. See Section 3.5.2.
- The TRA Team will make the final determination on the TRL for each CTE by reviewing pertinent documentation and applying the TRL calculator questions. This may include a review of the results of the project/programs team's self-assessment. The documented bases for the responses to the calculator questions are recorded during the meeting. TRA Team members should maintain notes from their information-gathering activities. See Section 3.5.3.
- The TRA Team decides writing assignments, schedules, and procedures for producing the TRA Report.
- The TRA Team Leader keeps the FPD/FPL, the Federal and Contractor Liaisons, and the EM CPOT, informed of the progress of the TRA. This may include periodic meetings with interested parties.
- At the conclusion of the on-site assessment, an out-briefing is conducted. The TRA Team Leader and/or individual TRA Team members present assessment results and highlight CTEs that do not meet the maturity expectations.

Draft the TRA Report: After the on-site assessment, the TRA Team members conduct due diligence reviews of presentations and documents to ensure that the bases for the TRL scoring are fully supported. TRL determinations are then finalized. See Section 3.5.4.

After the report sections have been written, the TRA Team Leader assembles the draft TRA Report and circulates it to the TRA Team. TRA Team comments are resolved, and a draft TRA Report is sent to the FPD/FPL and Contractor for factual accuracy review. See Section 3.5.5. (Note: the draft TRA Report will provide a starting point for either a revision of the existing TMP, if necessary, or development of the initial TMP).

Perform the Factual Accuracy Review: The purpose of the FPD/FPL and Contractor review is to identify factual inaccuracies.

Produce the Final Draft of the TRA Report: The TRA Team resolves comments from the factual accuracy review and produces a Final Draft TRA Report that is used as the basis for briefing the EM CPOT and other interested parties.

Brief the EM CPOT and Other Interested Parties: The TRA Team Leader and, as appropriate, selected TRA Team members brief the EM CPOT. Following the briefing, the TRA Report is finalized, circulated to, and signed off by, all TRA Team members, and submitted to the EM CPOT for approval.

Approve and Distribute the TRA Report: The EM CPOT approves the TRA Report and distributes it to interested parties.

3.5.1 On-Site Assessment Meeting

The Kick-Off Meeting marks the start of on-site assessment activities. The purpose of the Kick-Off Meeting is to:

- introduce the TRA Team and key project personnel,
- review the primary objective of the TRA and the identified assessment criteria,
- convey the logistics for TRA activities, and
- initiate the TRA.

The FPD/FPL and the TRA Team Leader are responsible for the Kick-Off Meeting planning, logistics, and performance. Attendance is open to interested parties, including the EM CPOT and the TRA Requester. Additionally, federal and contractor observers from other sites, DOE offices, or other federal offices, that may be considering deployment of the technology system (or similar) being assessed, or the use of the TRA process, should be encouraged to attend the Kick-Off Meeting.

At the Kick-Off Meeting, briefings may be presented by TRA Team Leader, EM CPOT, FPD/FPL, and appropriate Federal and Contractor subject matter experts. The EM CPOT may brief the TRA team on related technology maturation efforts, and how the TRA/TMP results will be used. Contractor personnel provide an overview of the technology and its development status. Other individuals may attend to answer questions. Briefings should include the applicable references, to the extent practical, to assist the TRA Team in the due diligence document review process. The briefings should also address questions submitted by the TRA Team in advance. A tour of the facilities may be included to aid the TRA Team understanding of the project.

The TRA Team Leader should hold a daily status meeting with the FPD/FPL and liaisons to cover progress and logistics for the next day.

Upon completion of the on-site assessment, the TRA Team should provide an out briefing of their initial findings related to CTEs, TRLs, and any recommendations. The TRA Team will respond to questions related to the review. Copies of materials presented at the out-brief meeting should be made available. The out-brief meeting may include a briefing by the FPD/ FPL or Contractor on their path forward for preparing a TMP.

Sample agendas for meetings held during the on-site assessment are provided in Attachment B.

3.5.2 CTE Identification

The EM definition of a CTE is the same as that found in DOE Guide 413.3-4A:

> A technology element is "critical" if the systems being acquired depend on the technology element to meet operational requirements (with acceptable development cost, and schedule and with acceptable production and operations costs) and if the technology element or its application is either new or novel. Said another way, an element that is new or novel or being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operational utility.

The identification of CTEs is fundamental to the TRA process and is the responsibility of the TRA Team. Early in TRA planning, the Federal and Contractor liaisons should compile a list of technology elements based on the project's/program's established technical work breakdown structure (product or system based) and process flowsheets. The organization that requested the TRA may recommend additional technology elements. The TRA Team then determines the CTEs using a two-step process, which utilizes two sets of criteria to evaluate each technology element. The criteria are provided in Attachment G. A technology element must have a positive response to at least one question in each criteria set for a determination as a CTE. For additional guidance on selecting a CTE see U.S. Department of Defense (DoD) TRA Guide Section 2, dated April 2011; and Appendix B of the DoD TRA Deskbook dated July 2009.

Technology is not just "new or novel" technology; it is also existing technology that may be fully mature but is being used for a different function or outside the architecture and operational environment for which it was originally designed. There are often technical or engineering issues/risks associated with incorporating existing technologies into new systems under development. Items to consider for existing technology:

- The technology application typically leads to problems based on past experience.
- Predicted obsolescence may lead to a technology issue.
- The performance being demanded from the technology exceeds previous requirements.

Similarly, interfaces to existing systems should be evaluated as potential CTEs. Integrating a new technology into an existing system and the ancillary system's requirements and capabilities are critical to ensuring success.

As the project/program evolves from concept through final design the CTEs may change as a result of the maturation of the technologies, the accumulation of new information, and opportunities to exploit technologies not previously considered. As the project/program progresses the technologies should be reassessed to determine if they are critical and whether they are mature enough to include in the final design.

TRA Team discussions should be utilized to obtain agreement on CTE determinations. If consensus cannot be reached, the TRA Team Leader makes the CTE determination.

3.5.3 TRL Assessment

A modified version of the DoD TRL Calculator is used during the conduct of EM TRAs. The TRL determination is a two-step process. First, a set of top-level questions (see Table H1 of Attachment H) is used to determine the anticipated TRL. The anticipated TRL is determined from the question with the first "yes" answer, starting from TRL 9. Second, evaluation of the detailed calculator questions (see Tables H2 through H7 of Attachment H) is started one level below the anticipated TRL. To attain a specific TRL, the CTE must receive a "yes" response to all questions at the TRL level. If the technology has not attained the maturity of the starting level, then the next level down is evaluated in turn until the TRL is determined. The overall TRL for the project/program is the lowest TRL for a CTE based on the completed TRL calculators.

Note, that if a system is broken down into a number of sub-systems, and the TRL of each sub-system is determined, the TRL of the entire system is equal to the lowest TRL found for the sub-systems. Thus, the TRL of the whole is equal to the lowest TRL of the parts.

The basis and supporting documentation for each TRL "yes" answer should be noted in the proper column of the TRL calculator. This information forms the starting point for the due diligence review. The TRL determination should be clearly and concisely documented in the text of the TRA Report. The completed question sets should be part of the TRA Report.

If technologies exist, the initial evaluation of the top level questions should be at most a TRL 5 until analysis and/or tests demonstrate a higher level.

EM has developed a set of questions to allow the determination of a TRL for the integrated waste processing system (WPS). Integration of the individual technology elements and CTEs into a functioning system is critical to success. Integration of system components begins at TRL 4 for CTEs or subsystems of multiple components and is completed at engineering scale demonstration for a fully integrated system by TRL 6. For a project, as defined in DOE Order 413.3B, these phases coincide with CD-1 and CD-2, respectively. For an Operations Activity, these phases coincide with completion of conceptual design and detail design, respectively.

The questions in WPS TRL calculator tables are designed to determine if:

- individual processing system technologies are properly integrated together and into existing systems,
- the processing system can treat the full range of materials it is intended to process, and
- the processing system yields a product that meets disposal path requirements.

The WPS TRL calculators were initially developed to assess CD-1 and CD-2; therefore, only TRL 4 and TRL 6 calculator questions have been prepared. However, if the integration has clearly moved beyond simple subsystems, but not completed an engineering scale fully integrated demonstration, the TRA Team may determine that the WPS TRL is beyond 4 and document the basis for this determination in the TRA Report. This flexibility is important because all CTEs may be at TRL 5, with no direct method (i.e., TRL calculator table) to evaluate the integrated WPS for TRL 5. Development of such a table is not deemed necessary as long as the TRA Team has the ability to objectively determine that a project/ program is at an overall TRL 5, when it is warranted. This flexibility avoids down-grading a technology system to TRL 4 when all CTEs are at a higher TRL and the integration has proceeded beyond TRL 4.

The WPS TRL calculators can be found in Tables H8 and H9 of Attachment H.

3.5.4 Due Diligence Reviews

Following the initial TRL determination, individual TRA Team members conduct due diligence reviews by detailed study of reference documents and, if needed, by personal interviews. Reviews of assigned CTE TRLs are completed and a written report of the TRL determination and supporting basis is provided. Where possible, breakout sessions should be scheduled concurrently to improve efficiency. To the extent possible, more than one TRA Team member should be present for all interview sessions. As interviews and document reviews are completed, the details of the review should be documented.

Information may indicate initial TRA Team determination of TRLs, or observations, recommendations, and conclusions may need to be altered. The TRA Team Leader should lead a discussion to determine the proper course of action. Past TRA Teams have sometimes found it necessary to alter initial TRL determinations that did not have adequate supporting documentation.

3.5.5 TRA Report

The purpose of the report is to document the TRA process, observations, recommendations, and conclusions including a comprehensive explanation of the TRL for each CTE. The TRA Team Leader is responsible for coordinating the report preparation. See Attachment D for the format of the report. The report is divided into sections that may be assigned to individual TRA Team members. The TRA Team Leader compiles an initial draft of the report and provides it to the TRA Team for review. It is then submitted to the FPD/FPL and Contractor for a factual accuracy review as described in Section 3.5.6. To expedite the schedule, these two reviews may be accomplished in parallel. The TRA Team incorporates comments and the revised draft TRA Report is used for briefing the EM CPOT and EM program office responsible for the project/program being reviewed. After EM CPOT comments are incorporated: the TRA Report is signed by the TRA Team and the EM CPOT; and the EM CPOT distributes the TRA Report.

As part of the process of finalizing the report, the TRA Team is to develop a TRA Summary document. See Attachment F for the suggested layout and content. The goal is to limit the summary to one page.

A key function of the TRA Summary, as well as the Executive Summary of the TRA Report, is to clearly document the overall TRL of the technology system with clear and concise descriptions of the ease or difficulty for maturing the specific CTEs to the desired TRL. Effort should be made by the TRA Team to provide an easily understandable description of the level of effort/resources required to advancing the maturity of the CTEs such that the maturation stage of the project/program is accurately and fairly represented.

Lessons learned that benefit future TRAs may be identified in the report. In the case of a separate lessons learned document, the TRA Report should be referenced within the document and the document should be filed with the TRA Report. In many cases, these lessons learned have been incorporated into this Guide as they are identified.

Examples of TRAs and TRA Summaries can be found on the EM website: http://energy.gov/em/technology-readiness-assessments

3.5.6 Factual Accuracy

The purpose of the factual accuracy review is to identify any errors in fact, or the logic that leads from the asserted facts to the stated conclusion. The factual accuracy review is conducted by the FPD/FPL and Contractor. The TRA Team must correct errors in fact that may result in a change in TRL scores or identified technical issues, or change conclusions. The TRA Team Leader should provide a response to the FPD/FPL on how the comments were addressed.

3.5.7 TRA Results Briefing

If required, a TRA Results Briefing may be conducted after issuance of the final TRA Report. The EM CPOT, with support from the FPD/FPL if desired, is responsible for presenting the results of the assessment to EM management. The briefing should include an overview of the TRL determinations and associated bases, recommendations, and general conclusions. A sample TRA Results Briefing agenda is provided as Attachment C.

Table 8 Implementation Tips for TRA Execution

Status Meetings

- Maintain regular communications between the TRA Team and the Project/Program such that neither is caught off guard by new information. Typically, a short daily meeting of key personnel is held at the end of each day of the on-site assessment.

Issue Capture and Resolution

- A database or table format is recommended to capture the technology elements assessed, responses to CTE criteria and TRL calculator questions, and other information necessary to facilitate the review and track open items and report preparation.
- A standard form for capturing information should be used. Standard items should include: name, e-mail, phone number, technology element, document identification, specific criteria, response, and follow-up items.
- The TRA Team should have a process for handling differences in professional opinions.

Report Preparation

- A technical editor should be available to the TRA Team to help in finalizing reports.
- Build the assessment report as the review progresses rather than waiting until the assessment activities are complete. Report development is facilitated if the project/program has conducted a prior TRA self-assessment and developed a TMP.

Comment Resolution

- The TRA Team members are responsible for resolving comments within their assigned areas.
- The TRA Team Leader resolves comments that are not specific to a particular technology area.
- The TRA Team members may document non-resolvable differences of opinion in a “minority report.”

Report Distribution / Approval / Closeout

- The TRA Team Leader should establish the distribution list for the report early in the assessment.

4.0 TECHNOLOGY MATURATION PLAN

4.1 Process Overview

Results of the TRA determine technology maturity needs, but not the difficulty to bring a technology to the desired level of maturity. A TMP establishes the steps to mature the technology and identifies the level of difficulty. The TMP outlines scope, schedule, and cost for bringing technologies to the desired level of maturity, and a basis for the development of test plans. The TMP should also include an initial evaluation of technology risk associated with implementing the technology and integration with existing systems, and describe risk handling strategies. If the scope, schedule, and costs, described in the TMP and test plans are not already in the project baseline, the TMP provides the basis for change packages.

It is recommended that the project/program complete a self-assessment TRA and update the existing TMP, or draft a TMP, prior to the independent TRA (see section 3.4).

4.2 TMP Preparation

The major steps in preparing a TMP are summarized below and are illustrated in the TRA/TMP Process diagram (Figure 4).

1. The Contractor prepares the draft TMP. Additional information on the desired content of the plan is provided below and in Attachment E.
2. The Contractor provides the draft TMP to the FPD/FPL for review. The TRA Team members, the EM program sponsor office and the EM CPOT may be included as part of the review. The reviews verify 1) responsiveness to gaps identified in the TRA; 2) reasonableness of the proposed approach; and 3) reasonableness of the proposed schedule, costs, and risks associated with technology maturation requirements.
3. As applicable, the Contractor resolves review comments, revises the TMP, and forwards the revised TMP to the FPD/FPL.
4. The FPD/FPL approves and distributes the final TMP to the Contractor, EM CPOT, and EM program sponsor office.
5. The FPD/FPL incorporates TMP details into project/program risk management plan.
6. If needed, the Contractor develops and approves test plans that contain detailed schedules and cost estimates for technology development. If the test plans require a change in project scope, schedule, and costs, the Contractor will also develop the necessary change packages (e.g., Baseline Change Proposals [BCPs]). The BCPs/change packages are forwarded to the FPD/FPL.
7. The FPD/FPL reviews and/or approves the BCPs/change packages, as appropriate, according to the execution plans of the project/program.

4.3 TMP Document

The TMP documents program needs to mature the technologies to meet mission's objectives. TMPs have three primary sections. The first provides a review of past technical assessments and the current TRLs, the second provides the plan to mature the technologies, and the third provides a plan to mature the integration of the CTEs and the integration of the technologies to existing systems. The gaps identified by TRL calculator questions are key inputs to the development of the last two sections.

The review of past technical assessments presents a summary of previous independent technical reviews, other technical assessments, and any previous TRAs that may have contributed to the need for the TMP. A listing of the current TRLs for each CTE is included. Previous technology development activities that brought the technology to its current state of readiness should be described.

The plan to mature each of the CTEs begins with a description of the approach used in defining the technology development activities. The description may include evaluating TRL calculator questions that received negative answers, risk assessments, and value engineering. The following should be taken into account:

- How critical the system is to mission success or safety
- Probability that the technology will prove successful
- Backup technologies or design concepts that can be substituted if the new technology or design solution cannot be elevated to TRL 6 or higher
- The cost, schedule, and performance penalty incurred if the backup solution is used
- A cost/benefit analysis of the development strategy
- Impacts of the strategy on other technical portions of the project.

After describing technology development activities, the plans to mature each CTE should be described. The maturation plan for each CTE should identify:

- Key technology addressed
- Objective
- Current state of art
- Technology development approach
- Scope
  - Specific tasks to be undertaken
  - Results to be achieved for a claimed advancement to a higher TRL
- Responsible organization for the maturation activities
- The TRL to be reached for each CD milestone (See section 2.4 for recommended TRLs for each CD milestone).
- The TRLs to be reached as the project/program progresses through turnover, readiness assessments, startup, and initial operations.
- Cost, schedule, milestones, and risks of these activities
- Fallback alternatives
- Off ramp(s) that will be taken if results are less than required at each critical decision milestone.

The plan to mature the technologies associated with the integration of the CTEs and the integration of the technologies to existing systems should begin with an analysis of the gaps identified by the WPS TRL calculator questions. The plans to mature these should be structured similar to the CTE areas.

The high-level schedule and budget (including the total maturation costs) for the major development activities for each CTE should be provided. Major decision points such as proceeding versus abandoning the current technology, or selection of a backup technology, should be identified. An annotated outline of a TMP is provided in Attachment E. Examples of TMPs can be found on the EM website:
http://energy.gov/em/technology-readiness-assessments.

4.4 Test Plans and Change Packages

After the TMP has been approved, the Contractor will prepare detailed test plans to conduct the technology development activities described in the TMP. The management and control of testing transition and turnover should be in accordance with the project's/program's execution plan. These test plans will include more detailed cost and schedule estimates to support preparation of a change package and BCP, if needed. The FPD/FPL will review and/or approve any needed change packages or BCPs, as appropriate, according to the execution plans of the project/program.

4.5 TMP Execution

The Contractor should execute the TMP according to the approved test plans. Significant changes in scope and schedule may require formal change control, as appropriate, according to the execution plans of the project/program. Monitoring of TMP progress should be completed per the execution plans of the project/program (i.e., Project Execution Plan, and Quality Assurance Plan).

Technical reports should be written as major technology development tasks are completed. A Final Technical Report will be prepared when all of the technology development tasks in the TMP have been completed to obtain TRL 6. The status of technology maturation activities beyond TRL 6 should be captured in a technical report or incorporated into status reports for the current phase.

Upon completion, or near completion, of the activities in the TMP to achieve the next TRL, a new TRA should be conducted to confirm that the CTEs have reached desired TRLs.

5.0 TRA/TMP Lessons Learned

General lessons learned by EM in the course of carrying out the TRA/TMP process are listed in Table 9.

Table 9 TRA/TMP Lessons Learned

- Every effort should be made to keep the process transparent, i.e., structured, objective, and clearly documented.
- The process enforces discipline on EM and the Contractor.
- Contractors and EM generally like the TRA language and formalism. Technical communication is greatly improved.
- Technologists like having the well-defined standards that TRLs provide.
- Documentation is critical. The governing philosophy is, "If it's not written down, it doesn't exist."
- The TRA/TMP process is a useful tool for comparing candidate technologies. However, note the caution - *A TRL, by itself, does not give any indication of the degree of difficulty to mature a technology, i.e., the risks, scope, schedule, and costs associated with developing a technology to desired levels of maturity.* The TRA should be followed by a TMP in order for comparisons to be made.
- The process assists in identification of specific actions needed to reduce programmatic risk to final commitment and major investment in a technology.
- Proper identification of the relevant environment, especially feed characterization, is critical.
- Product definition/requirements are critical.
- To reach TRL 6, all components must be tested, preferably in a complete system.
- The TRL calculator questions are useful to focus discussion on key areas.
- Evaluation of process flow, connecting the technologies in a flowsheet, is critical but remains a challenge.
- The process has been proven very helpful even for relatively mature projects.
- It is often the peripheral technologies such as systems for processing off gases, recycle streams, and secondary waste streams that are untested, and present difficult challenges.
- Expert TRA Team members frequently become valued contributors to future development.
- Project personnel almost always think project technologies are more mature than they really are.
- Almost all project managers go from, "Is this really necessary?" to "Thank you so much."
- It is all about helping the project/program to be successful.

6.0 ATTACHMENTS

Attachment A, TRA Plan
Attachment B, On-Site Assessment Meeting Agenda
Attachment C, TRA Results Briefing Agenda
Attachment D, TRA Report Format
Attachment E, Technology Maturation Plan Format
Attachment F, TRA Summary
Attachment G, CTE Identification Criteria
Attachment H, TRL Calculators

Attachment A, TRA Plan

1.0 INTRODUCTION

Briefly state who requested the TRA, what organization is responsible for conducting the TRA, and what technology is to be assessed. State where the technology is being developed (i.e., facility, site).

2.0 PURPOSE

Briefly state the objective of the TRA. Specifically, state how the customer will use the results from the TRA. Additionally, state any other drivers for conduct of the TRA (e.g., CD milestone support, technology downselect support).

3.0 TECHNOLOGY BACKGROUND

Provide a general description of the technology and the project supported by the technology. The description should include details regarding the function that the technology accomplishes for the project and a brief summary of status of the technology development. Additionally, summarize the results of any previous TRAs conducted on the technology.

4.0 TRA Team

Include a table that lists the position, name, title, company, and area of expertise of each TRA Team member.

Position	*Name*	*Title*	*Company*	*Area of Expertise*
Team Leader				
Team Member				

5.0 TRA ESTIMATED SCHEDULE

Task Number	Projected Duration*	Task Description
1	6 weeks	Establish TRA Team
2	4 weeks	Distribute critical documents to TRA Team
3	4 weeks	Conduct on-site assessment activities
4	4 weeks	Draft TRA Report
5	4 weeks	Issue Final Report

** The projected durations are recommended durations and may be modified depending on the project/program.*

7.0 DEFINITIONS

8.0 REFERENCES

Attachment B, On-Site Assessment Meeting Agenda

Topic	Presenter
Initial / Kick-Off Meeting	
TRA Team and Field Office Introductions	TRA Team Leader and Field Office Representative or Contractor Liaison
Purpose of Assessment	TRA Team Leader
Scope of Assessment	TRA Team Leader
TRA Process Overview	TRA Team Leader
Technology Overview and Status	Field Office Representative or Contractor Liaison
Site Tour (as needed)	Field Office Representative or Contractor Liaison
Conduct Initial Assessment	TRA Team
Daily Status Brief to FPD/FPL and Liaisons	TRA Team Leader
Conclusion of On-Site Assessment	
Provide Out-Briefing of Initial TRA Results, to include: • CTE determinations • TRL determinations • Preliminary recommendations • General conclusions	TRA Team Leader

Attachment C, TRA Results Briefing Agenda

Topic	Presenter
Purpose of Briefing	EM CPOT
Presentation of TRA results ▪ Summary of TRLs ▪ Key Recommendations ▪ Conclusions	EM CPOT and/or FPD/FPL
Discussion	All
Path Forward for Addressing Recommendations	All

Attachment D, TRA Report Format

Examples of TRAs can be found on the EM website:
http://energy.gov/em/technology-readiness-assessments

EXECUTIVE SUMMARY

Briefly state who requested the TRA, what organization was responsible for conducting the TRA, what technology was assessed. Provide a summary table of the CTEs and corresponding TRLs determined during the review.

1. INTRODUCTION

- *Provide project/program background.*
- *Provide a detailed description of the technology that was assessed.*
- *Discuss objectives of the TRA.*

2. TRA PROCESS

- *Provide description of the TRA process, including pertinent background information on recent changes/enhancements to the process.*
- *Provide an overview of the approach used to conduct the TRA. Reference applicable planning documents.*
- *Provide discussion of the process to determine the CTEs.*

3. RESULTS

- *Provide the following for each CTE assessed:*
  - ***Function***
    Describe the CTE and its function.
  - ***Relationship to Other Systems***
    Describe how the CTE interfaces with other systems.
  - ***Development History and Status***
    Summarize pertinent development activities that have occurred to date on the CTE.
  - ***Relevant Environment***
    Describe relevant parameters inherent to the CTE or the function it performs.
  - ***Comparison of the Relevant Environment and the Demonstrated Environment***
    Describe differences and similarities between the environment in which the CTE has been tested and the intended environment when fully operational.
  - ***TRL Determination***
    State the TRL determined for the CTE and provide the basis justification for the TRL.

- *Provide a discussion of the results of the assessment of the integrated Waste Processing System, if applicable.*

4. CONCLUSIONS, OBSERVATIONS AND RECOMMENDATIONS

- *Provide a summary of the conclusion and recommendations.*
- *Acknowledge good practices by project teams, etc.*

5. LESSONS LEARNED AND CONTINUOUS PROCESS IMPROVEMENT

- *Discuss opportunities and practices identified that will improve the overall TRA process.*

Attachment D, TRA Report Format continued

6. REFERENCES

APPENDICES

- *Include the following planning documents:*
  - *TRA Plan*
  - *Supporting documentation for identification of CTEs*
  - *Completed tables:*
    - *Top Level Questions for Determining Anticipated TRL (Attachment H Table H.1)*
    - *TRL Calculator Questions for CTE (Attachment H Tables H.2 through H.7)*

  - *List of support documentation for TRL determination*
  - *TRL Summary table*
  - *Lessons Learned*
  - *Team biographies*

Attachment E, Technology Maturation Plan Format

Notes:

- **a)** The TMP is a high level summary document. It is not a collection of detailed test plans.
- **b)** Examples of TMPs can be found on the EM website: http://energy.gov/em/technology-readiness-assessments

TABLE OF CONTENTS
LIST OF TABLES
LIST OF FIGURES
ABBREVIATIONS AND ACRONYMS

1.0 INTRODUCTION

- Purpose of the Project

Provide a brief summary of the project's mission, status, technology(s) being deployed, etc.

- Purpose of the TMP
  Describe the objectives and content of the TMP and relate it to the status of the project and any upcoming CDs.

2.0 TECHNOLOGY ASSESSMENTS OF THE PROJECT

- Summary of Previous Independent Technical Reviews
  Summarize any previous Independent Technical Reviews or other technical assessments that may have contributed to the need for a TRA and the TMP.
- Summary of Previous Technology Readiness Assessment(s)
  Describe the results of previous TRAs with particular emphasis on the latest TRA that is driving the TMP. Include the definition of TRLs as used in the TRA. Discuss the CTEs that were determined for the project.
- Technology Heritage
  Summarize the previous technology development activities that brought the technology to its current state of readiness. Include discussions of any full-scale plant deployments of the technology in similar applications.
- Current Project Activities and Technology Maturation
  Describe ongoing technology development activities (if any) that were initiated prior to the TMP. Completion of these activities should define the starting point for the TMP.
- Management of Technology Maturity
  Indicate the DOE and contractor organizations that will be responsible for managing the activities described in the TMP. Include a brief discussion of key roles and responsibilities.

3.0 TMP

- Development of Technology Maturation Requirements
  Describe the approach used in defining the required technology development activities that will be conducted as described in the TMP. These could include evaluating incomplete questions in the TRL Calculator, risk assessments, and value engineering.
- Life-Cycle Benefit
  Briefly discuss life-cycle benefits to the project that will result from successful completion of the TMP technology development activities.

Attachment E, Technology Maturation Plan Format continued

- Specific TMPs
  Maturation plans for each CTE will be described following the format below for each CTE that was defined in the latest TRA.
  - CTE A
    - Key Technology Addressed *(Describe the function that the CTE carries out in the project)*.
    - Objective *(Succinctly state the objective of the CTE)*
    - Current State of Art *(Describe in one paragraph the current status of the CTE including the specific TRL assigned in the latest TRA)*.
    - Technology Development Approach *(In paragraph form, describe how the needed technology development work to reach TRL 6 will be performed. This could include the performing organization, location, simulant versus actual waste, etc.)*.
    - Scope *(Provide a list of the key steps to be taken in performing the work. Include a table that gives milestones, performance targets, TRL achieved at milestones, and a rough order of magnitude cost of development. Include in this section the risks associated with the planned strategy and off ramps/decision points if results are less than expected at key milestones and CDs)*.

Example of Scope Table

Milestones		**Performance Targets**	**TRL Achieved at Milestone**
YYYY	Complete laboratory/bench scale	Demonstrate with actual material at laboratory/bench scale	4

  - CTE B
    - Key Technology Addressed
    - Objective
    - Current State of Art
    - Technology Development Approach
    - Scope
  - CTE C (etc., as needed)

4.0 PLAN TO MATURE SYSTEM INTEGRATION

Plans to mature system integration will be described in this section. This includes the integration of CTEs and the integration of the system to existing systems. Inputs to these plans could include evaluating incomplete questions in the WPS TRL Calculator, risk assessments, value engineering studies, evaluations of interface requirements, and the evaluations of the difficulty to mature the technologies.

5.0 TECHNOLOGY MATURITY SCHEDULE

Provide and briefly discuss a high-level schedule of the major technology development activities for each CTE. Any major decision points such as proceeding with versus abandoning the current technology, selection of a back-up technology, etc. should be included. Detailed schedules should be given in test plans or used for status meetings during implementation.

Attachment E, Technology Maturation Plan Format continued

6.0 SUMMARY TECHNOLOGY MATURITY BUDGET

Present the rough order of magnitude costs to reach TRL 6 for each major technology development activity for all CTEs in the project. Include the total technology maturation costs.

7.0 REFERENCES

Appendix A.	Crosswalk of identified previous independent reviews and assessments (if applicable to support information in Section 2)
Table 1, etc.	Table(s) for each CTE, listing of test activities, planned completion date, performance targets, resulting TRL level as each increment of testing is completed, and rough order of magnitude costs.
Table X.	Technology Maturity Budget for Project
Figure 1.	Process Flow Diagram (for technology being assessed)
Figure 2.	Technology Maturity Schedule
Figure 3.	Project Execution Strategy Diagram

Attachment F, TRA Summary

DOE Site: Idaho National Lab/INL
EM Project: Calcine Disposition Project/CDP
TRA Report Date: February 2011

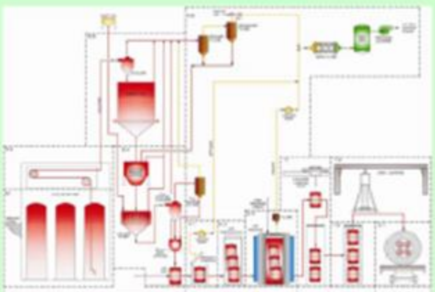
TRA-9

Technology Readiness Assessment Summary

United States Department of Energy Office of Environmental Management (DOE-EM)

Preliminary TRA of the Calcine Disposition Project

Why DOE-EM Did This Review



Calcine HIP Treatment Process Flow Diagram

The Idaho high-level waste calcine is solid granular material designated through an amended ROD (issued Dec. 2009) to undergo treatment by a Hot Isostatic Press (HIP) process. The HIP process, possibly with additives, converts the calcine to a monolithic waste form with durability and leach rates comparable to those of borosilicate glass. The calcine disposition project is currently in the conceptual design phase and anticipates critical decision 1 (CD-1) approval in late 2012 authorizing the preliminary design phase. For CD-1 approval, it is typically recommended that the selected technology be at a Technology Readiness Level (TRL) of 4 or higher. The objective of this assessment was to identify the Critical Technology Elements (CTEs) of the HIP treatment process and assign the TRLs that are anticipated by late 2010 in preparation for CD-1.

What the TRA Team Found

The assessment team identified the eleven CTEs listed below along with the associated TRLs expected to be achieved prior to CD-1 (now scheduled for 2012):

- Retrieval//Pneumatic Transfer System (TRL=4)
- Batching and Mixing System (TRL=4)
- Ceramic Additive Formulation (TRL=3)
- Hot Isostatic Pressing Can Design (TRL=3)
- Hot Isostatic Pressing Can Containment (TRL=2)
- HIP Can Filling and Closure (TRL=4)
- Bakeout System (TRL=4)
- Canister loading/Closure (TRL=4)
- Remote Operation and Maintenance (TRL=4)
- Characterization: feed, admixture, product (TRL=4)
- Simulant Formulation (TRL=3)

The team identified several significant project risks, among which were the following:

- Design of the facility is being restricted to the Integrated Waste Treatment Unit (IWTU) footprint for systems requiring Performance Class-3 construction; meeting this requirement and the December 2035 completion date will be a challenge.
- If additional sampling of calcine is required, designing and constructing the facility within the IWTU footprint may be impractical.

Significant supporting documentation was not available to the assessment team at the time of the review. A follow-up assessment will be required prior to CD-1.

What the TRA Team Recommended

- The project should ensure that all required documents be complete and available to the review team for all future assessments.
- The project should complete discussions of waste form requirements with the EPA and EM as soon as possible.
- A full-scale mockup facility should be built and operated to achieve a TRL of 6 for CD-2.
- The project's technology maturity plan should identify all necessary development work and address achieving a TRL of 6 for all CTEs prior to CD-2.

To view the full TRA reports, please visit this web site:
http://www.em.doe.gov/Pages/ExternalTechReviews.aspx

TRA Summary: June 2011

The objective of a Technology Readiness Assessment (TRA) is to determine the maturity of certain key technologies, identified as Critical Technology Elements (CTEs), using a systematic, metric-based process and to evaluate the readiness of these technologies for insertion into a project design.

Environmental Management
safety ✧ performance ✧ cleanup ✧ closure

www.em.doe.gov

Attachment G, ical Technology Elements (CTE) Identification Criteria

A CTE is identified if there is at least one positive response for each set of criteria.

Set 1 - Criteria	Yes	No
• Does the technology have a significant impact on a functional requirement of the process or facility?		
• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?		
• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?		
• Are there uncertainties in the definition of the end state requirements for this technology?		
• Do limitations in the understanding of the technology impact the safety of the design?		

Set 2 - Criteria	Yes	No
• Is the technology new or novel?		
• Is the technology modified?		
• Has the technology been repackaged so a new relevant environment is realized?		
• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?		
• Does the technology represent new hazards or safety-related issues that have not been assessed and/or mitigated?		

Attachment H, Technology Readiness Level Calculators

Attachment H, Technology Readiness Level Calculator

Table H1. Top Level Questions for Determining Anticipated TRL

Top-Level Question		Yes/No	If Yes, Then Basis and Supporting Documentation
TRL 9	Has the actual equipment/process successfully operated in the full operational environment (hot operations)?		
TRL 8	Has the actual equipment/process successfully operated in a limited operational environment (hot commissioning)?		
TRL 7	Has the actual equipment/process successfully operated in the relevant operational environment (cold commissioning)?		
TRL 6	Has engineering scale equipment/process testing been demonstrated in a relevant environment?		
TRL 5	Has laboratory/bench scale equipment/process testing been demonstrated in a relevant environment?		
TRL 4	Has laboratory/bench scale testing, at a minimum, of similar equipment systems been completed in a simulated environment? For some systems, such as mechanical systems, this may require full-scale prototype testing.		
TRL 3	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?		
TRL 2	Has an equipment and process concept been formulated?		
TRL 1	Have the basic process technology process principles been observed and reported?		

Attachment H, Technology Readiness Level Calculator (continued)

Table H.2. TRL 1 Questions for Critical Technology Element

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. "Back of envelope" understanding of the environment.	
T		2. Physical laws and assumptions used in new technologies defined.	
T		3. Paper studies confirm basic principles.	
P		4. Initial scientific observations reported in journals/conference proceedings/technical reports.	
T		5. Basic scientific principles observed and understood.	
P		6. Know who cares about the technology, e.g., sponsor, funding source, etc.	
T		7. Research hypothesis formulated.	
T		8. Basic characterization data exists.	
P		9. Know who would perform research and where it would be done.	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment H, Technology Readiness Level Calculator (continued)

Table H.3. TRL 2 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
P		1. Customer identified and has expressed interest, i.e., know what program the technology would support.	
T		2. Potential system or components have been identified.	
T		3. Paper studies show that application is feasible; to include compliance with DOE Standard (STD) 1189-2008, *Integration of Safety into the Design Process*.	
T		4. An apparent theoretical or empirical design solution identified.	
T		5. Basic elements of technology have been identified.	
T		6. Components of technology have been partially characterized.	
T		7. Performance predictions made for each element.	
T		8. Modeling & Simulation used to verify physical principles.	
P		9. System architecture defined in terms of major functions to be performed.	
T		10. Rigorous analytical studies confirm basic principles.	
P		11. Analytical studies reported in scientific journals/conference proceedings/ technical reports.	
T		12. Individual parts of the technology work.	
T		13. Know what output devices are available.	
P		14. Preliminary strategy to obtain TRL 6 developed (e.g., scope, schedule, cost); to include compliance with DOE STD 1189-2008.	
P		15. Know capabilities and limitations of researchers and research facilities.	
T		16. The scope and scale of the waste problem has been determined.	
T		17. Know what experiments are required (research approach).	
P		18. Qualitative idea of risk areas (cost, schedule, performance).	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment H, Technology Readiness Level Calculator (continued)

Table H.4. TRL 3 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
P		1. Some key process and safety requirements are identified; to include compliance with DOE STD 1189-2008, *Integration of Safety into the Design Process*.	
P		2. Key process parameters/variables and associated hazards have begun to be identified; to include compliance with DOE STD 1189-2008.	
T		3. Predictions of elements of technology capability validated by analytical studies.	
P		4. The basic science has been validated at the laboratory/bench scale.	
T		5. Science known to extent that mathematical and/or computer models and simulations are possible.	
P		6. Preliminary system performance characteristics and measures have been identified and estimated.	
T		7. Predictions of elements of technology capability validated by Modeling and Simulation (M&S).	
M		8. Basic laboratory research equipment to verify physical principles.	
T		9. Predictions of elements of technology capability validated by laboratory experiments.	
P		10. Customer representative identified to work with development team.	
P		11. Customer participates in requirements generation.	
P		12. Requirements tracking system defined to manage requirements creep.	
M		13. Design techniques have been identified/developed.	
T		14. Paper studies indicate that system components ought to work together.	
P		15. Customer identifies technology need date.	
T		16. Performance metrics for the system are established (What must it do).	
P		17. Scaling studies have been started.	
M		18. Current manufacturability concepts assessed.	

Table H.4. TRL 3 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
M		19. Sources of key components for laboratory/bench testing identified.	
T		20. Scientific feasibility fully demonstrated.	
T		21. Analysis of present state of the art shows that technology fills a need.	
P		22. Risk areas identified in general terms.	
P		23. Risk mitigation strategies identified.	
P		24. Rudimentary best value analysis performed for operations.	
T		25. Key physical and chemical properties have been characterized for a number of waste samples.	
T		26. A simulant has been developed that approximates key waste properties.	
T		27. Laboratory/bench scale tests, at a minimum, on a simulant have been completed.	
T		28. Specific waste(s) and waste site(s) has (have) been defined.	
T		29. The individual system components have been tested at the laboratory/bench scale, at a minimum. This may require full-scale prototype component testing for some types of technologies, such as mechanical systems.	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment H, Technology Readiness Level Calculator (continued)

Table H.5. TRL 4 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T		1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed; to include compliance with DOE STD 1189-2008, *Integration of Safety into the Design Process*.	
M		2. Components tested are surrogates for system components. This will be at laboratory/bench scale at a minimum, but may be at larger scale for some technologies, such as mechanical systems.	
T		3. Individual components tested in laboratory or by supplier.	
T		4. Subsystems composed of multiple components tested at laboratory/bench scale using simulants.	
T		5. Modeling & Simulation used to simulate some components and interfaces between components.	
P		6. Overall system requirements for end user's application are known and documented.	
P		7. System performance metrics measuring requirements have been established.	
P		8. Laboratory/bench testing requirements derived from system requirements are established.	
T		9. Laboratory experiments with available components show that they work together.	
T		10. Analysis completed to establish component compatibility (Do components work together).	
P		11. Science and Technology (S&T) Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor).	
T		12. Technology demonstrates basic functionality in simulated environment.	

Table H.5. TRL 4 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
M		13. Scalable technology prototypes have been produced (Can components be made bigger than laboratory/bench scale).	
P		14. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance).	
M		15. Equipment scale-up relationships are understood/accounted for in technology development program.	
T		16. Controlled laboratory environment used in testing.	
P		17. Initial cost drivers identified.	
M		18. Integration studies have been started.	
P		19. Formal risk management program initiated.	
M		20. Key manufacturing processes for equipment systems identified.	
P		21. Scaling documents and designs of technology have been completed.	
P/T		22. Functional process description developed. (Systems/ subsystems identified).	
T		23. Low fidelity technology “system” integration and engineering completed in a laboratory environment, at a minimum. For some technologies, such as mechanical systems, this may require full scale prototype testing.	
T		24. Key physical and chemical properties have been characterized for a range of wastes.	
T		25. A limited number of simulants have been developed that approximate the range of waste properties.	
T		26. Laboratory/bench scale tests, at a minimum, on a limited range of simulants have been completed.	
T		27. Process/parameter limits and safety control strategies are being explored.	
T		28. Test plan documents for laboratory/bench, or appropriate, scale tests completed.	
P		29. Technology availability dates established.	

Table H.5. TRL 4 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T		30. If laboratory/bench scale tests for a limited range of wastes have not been completed, is there sufficient technical justification to proceed to the next phase based on the simulant testing that has been completed.	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment H, Technology Readiness Level Calculator (continued)

Table H.6. TRL 5 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T		1. The relationships between major system and sub-system parameters are understood on a laboratory/bench scale.	
T		2. Plant size components available for testing.	
T		3. System interface requirements known. (How would system be integrated into the plant?)	
P		4. Preliminary design engineering has begun	
T		5. Requirements for technology verification established, to include testing and validation of safety functions.	
T		6. Interfaces between components/subsystems in testing are realistic (bench top with realistic interfaces).	
M		7. Prototypes of equipment system components have been created (know how to make equipment).	
M		8. Manufacturing techniques have been defined to the point where largest problems defined.	
M		9. Availability and reliability (RAMI) target levels identified.	
T		10. Laboratory environment for testing modified to approximate operational environment; to include testing and validation of safety functions.	
T		11. Component integration issues and requirements identified.	
P		12. Detailed 3D design drawings and P&IDs have been completed to support specification of an engineering-scale testing system.	
T		13. Requirements definition with performance thresholds and objectives established for final plant design.	
P		14. Preliminary technology feasibility engineering report completed; to include compliance with DOE STD 1189-2008, *Integration of Safety into the Design Process*.	

Table H.6. TRL 5 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T		15. Integration of modules/functions demonstrated in a laboratory/bench-scale environment.	
T		16. Formal control of all components to be used in final prototypical test system.	
P		17. Configuration management plan in place.	
T		18. The range of all relevant physical and chemical properties has been determined (to the extent possible).	
T		19. Simulants have been developed that cover the full range of waste properties.	
T		20. Testing has verified that the properties/performance of the simulants match the properties/ performance of the actual wastes.	
T		21. Laboratory/bench scale tests, at a minimum, on the full range of simulants using a prototypical system have been completed – results validate design.	
T		22. Laboratory/bench scale tests, at a minimum, on a limited range of real wastes using a prototypical system have been completed – results validate design.	
T		23. Test results for simulants and real waste are consistent.	
T		24. Laboratory/bench to engineering scale scale-up issues are understood, if applicable, and resolved; to include testing and validation of safety functions.	
T		25. Limits for all process variables/parameters and safety controls are being refined.	
P		26. Test plan documents for engineering-scale tests completed.	
P		27. Risk management plan documented; to include compliance with DOE STD 1189-2008.	
P		28. Test plan for laboratory/bench scale, at minimum, tests executed – results validate design; to include testing and validation of safety functions.	

Table H.6. TRL 5 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
P		29. Finalization of hazardous material forms and inventories, completion of process hazard analysis, and identification of system/components level safety controls at the appropriate preliminary design phase.	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment H, Technology Readiness Level Calculator (continued)

Table H.7. TRL 6 Questions for Critical Technology Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. The relationships between system and sub-system parameters are understood at engineering scale allowing process/design variations and tradeoffs to be evaluated.	
M		2. Availability and reliability (RAMI) levels established.	
P		3. Preliminary design drawings for final plant system are complete; to include compliance with DOE STD 1189-2008, *Integration of Safety into the Design Process*.	
T		4. Operating environment for final system known.	
P		5. Collection of actual maintainability, reliability, and supportability data has been started.	
P		6. Performance Baseline (including total project cost, schedule, and scope) has been completed.	
T		7. Operating limits for components determined (from design, safety and environmental compliance).	
P		8. Operational requirements document available; to include compliance with DOE STD 1189-2008.	
P		9. Off-normal operating responses determined for engineering scale system.	
T		10. System technical interfaces defined.	
T		11. Component integration demonstrated at an engineering scale, at a minimum. May include full-scale prototype for some technologies, such as mechanical systems.	
P		12. Analysis of project timing ensures technology will be available when required	
P		13. Have established an interface control process.	
P		14. Acquisition program milestones established for start of final design (CD-2).	
M		15. Critical manufacturing processes prototyped.	
M		16. Most pre-production hardware is available to support fabrication of the system.	
T		17. Engineering feasibility fully demonstrated.	

Table H.7. TRL 6 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
M		18. Materials, process, design, and integration methods have been employed (e.g., can design be produced?)	
P		19. Technology "system" design specification complete and ready for detailed design.	
T		20. Engineering-scale system is high-fidelity functional prototype of operational system.	
P		21. Formal configuration management program defined to control change process.	
P		22. Final technical report on technology completed; to include compliance with DOE STD 1189-2008. Report is a summary of technology development activities.	
M		23. Process and tooling are mature to support fabrication of components/system.	
T		24. Engineering-scale tests, at a minimum, on the full range of simulants using a prototypical system have been completed – results validate design.	
T		25. Engineering to full-scale scale-up issues are understood and resolved.	
T		26. Test results are consistent for laboratory/bench and engineering-scale experiments, and/or prototype testing as applicable.	
M		27. Production demonstrations are complete (at least one time).	
P		28. Integration demonstrations of the CTE have been completed (e.g., construction of testing system); to include testing and validation of safety functions.	
P		29. Finalization of hazardous material forms and inventories; completion of process hazard analysis, identification of system/components level safety controls at the appropriate preliminary/final design phase.	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Waste Processing System Technology Readiness Level Calculators, TRL 4 and TRL 6, for assessing system integration.

Table H.8. TRL 4 Questions for Waste Processing System (WPS)			
CTE:			
	Y/N	**Questions**	**Basis and Supporting Documents**
Processing		1. Is the WPS, as it appears in the conceptual design, intended to accept the full range of wastes to be processed?	
		2. Is the WPS capable of meeting targets for startup and completion of waste processing?	
		3. Have the target operational and performance requirements for the WPS been determined?	
		4. Have all technology elements (TEs) that require an increase or change in capability been identified as CTEs?	
		5. Has WPS process flow been modeled?	
		6. Have WPS single point failures been identified?	
		7. Can TEs be sized to meet WPS throughput requirements?	
		8. Have all new or novel operating modes of the WPS been modeled and/or tested at laboratory/bench scale?	
		9. Have all recycle streams been identified and included in the conceptual design process flow models?	
		10. Have the key safety aspects of the WPS related to processing been identified?	
		11. Are appropriate measures in place to ensure safe operation of the processing activities?	
Disposal		12. Will the WPS produce a product or products that meet disposal path requirements?	
		13. Are all WPS waste streams identified and characterized to the extent necessary for conceptual design?	
		14. Can all WPS waste streams, including, process liquids, off gases, and solids identified in the conceptual design be treated and disposed	
		15. Will the waste streams meet the waste acceptance criteria of the proposed disposition facilities/sites?	
		16. Have the disposition facilities/site been contacted to ensure that the waste forms are compatible with facility/site **operations, procedures, and regulations**?	
		17. Have the key safety aspects of the WPS related to disposal been identified?	
		18. Are appropriate measures in place to ensure safe operation of the disposal activities?	
Interfaces		19. New or novel interfaces among WPS systems have been identified as CTEs?	

Table H.8. TRL 4 Questions for Waste Processing System (WPS)			
CTE:			
	Y/N	**Questions**	**Basis and Supporting Documents**
		20. Are all WPS technology interfaces and dependencies determined and understood at the conceptual level?	
		21. Can all WPS components be successfully mated?	
		22. Are the processing modes of the TEs (e.g., batch, continuous) compatible?	
		23. Have the key safety aspects of the WPS related to disposal been identified?	
		24. Are appropriate measures in place to ensure safe operation of the disposal activities?	

Table H.9. TRL 6 Questions for the Waste Processing System (WPS)			
CTE:			
	Y/N	**Questions**	**Basis and Supporting Documents**
Processing		1. Have all TEs that require an increase or change in capability been identified as CTEs?	
		2. Can the WPS accept the full range of wastes to be processed?	
		3. Is the WPS capable of meeting targets for startup and completion of waste processing?	
		4. Have the target operational and performance requirements for the WPS been determined?	
		5. Have major sections of the WPS and their interfaces been modeled and/or tested?	
		6. Has WPS data collection and data flow been modeled/tested?	
		7. Has WPS process flow and process control been modeled/tested?	
		8. Have WPS CTE single point failures (process and safety) been identified?	
		9. Can TEs be sized to meet WPS throughput requirements?	
		10. Have all new or novel operating modes of the WPS been modeled and/or tested?	
		11. Are all recycle and secondary streams fully characterized?	
		12. Are all recycle and secondary streams included in process models?	
		13. Have the key safety aspects of the WPS related to processing been identified?	
		14. Are appropriate measures in place to ensure safe operation of the processing activities?	
		15. Is the appropriate documentation in place that adequately describes the safety features related to processing, and their functions in the overall integrated WPS?	
Disposal		16. Will the WPS produce a product or products that meet disposal path requirements?	
		17. Are all WPS waste streams identified?	
		18. Have the waste streams produced by the WPS been fully characterized?	
		19. Has a disposition path been determined for each waste stream, including, process liquids, off gases, and solids?	
		20. Will the waste forms meet the waste acceptance criteria of the proposed disposition facilities?	
		21. Have the disposition facilities/sites been contacted to ensure that the waste streams are compatible with disposal facility/site **operations, procedures, and regulations**?	

Table H.9. TRL 6 Questions for the Waste Processing System (WPS)			
CTE:			
	Y/N	**Questions**	**Basis and Supporting Documents**
		22. Have the key safety aspects of the WPS related to disposal been identified?	
		23. Are appropriate measures in place to ensure safe operation of the disposal activities?	
		24. Is the appropriate documentation in place that adequately describes the safety features related to disposal, and their functions in the overall integrated WPS?	
Interfaces		25. Are all WPS technology interfaces and dependencies determined and understood?	
		26. New or novel interfaces among WPS systems have been identified as CTEs?	
		27. Have all WPS TE interfaces been modeled or tested?	
		28. Are the processing modes of the TEs (e.g., batch, continuous) compatible?	
		29. Have the key safety aspects of the WPS related to disposal been identified?	
		30. Are appropriate measures in place to ensure safe operation of the disposal activities?	
		31. Is the appropriate documentation in place that adequately describes the safety features related to disposal, and their functions in the overall integrated WPS?	

7.0 APPENDICES

Appendix 1, TRL 7 (Working Draft)
Appendix 2, Software TRA (Working Draft)

These appendices are working drafts. They are published here for information. Teams may use this information as they deem appropriate. Comments on this information should be sent to the EM CPOT. After these guides are piloted during appropriate technology assessments, they will be updated and fully incorporated in the guide.

Appendix 1, TRL 7 Calculator

Working Draft

Integration of Technology and Operational Readiness

Over the past years, DOE has implemented several initiatives to improve performance in technical, safety and project execution. These initiatives have resulted in a number of requirements and guidance that need to be addressed as a project moves towards completion. These requirements and guidance are documented in several documents and they include:

- DOE-O-425.1D, *Verification of Readiness to Startup or Restart Nuclear Facilities* – when coupled with DOE-STD-3006-2010, *Planning and Conducting Readiness Reviews*, provides requirements and guidance on how to meet the requirements for evaluating the operational readiness of new or modified nuclear facilities prior to startup (or restart).

- DOE-G-413.3-4A, *Technology Readiness Assessment Guide* – which provides descriptive information for later Technology Readiness Levels (TRL 7 through 9), but does not provide examples of detailed criteria for assessing whether these TRL's have been achieved.

- DOE-G-413.3-16A, *Project Completion/Closeout Guide* – which chronicles the latter stages of project management, and provides some top-level discussion of the integration of operational and technology readiness on a project.

Taken individually, these DOE documents could be viewed to involve an excessive number of assessments or reviews and reports during the latter stages of a project; for example:

- DOE-O-425.1D and DOE-STD-3006-2010 – involve a Startup Notification Report (SNR) issued for projects at least one year prior to startup; a Plan of Action (POA) that provides detailed planning information to implement the requirements of DOE-O-425.1D for a specific project, including the breadth and depth anticipated for the review and identification of the readiness review team leader (this must be completed no later than 6 months prior to the startup); the readiness review leader identified by the POA then works with his selected review team to develop the detailed Lines of Inquiry (LOIs) that will be used to evaluate operational readiness (which includes a technical review of the process) and, with the team membership and review schedule, make up the major parts of the Implementation Plan for readiness review; as part of the readiness review, the team is required to review the project/facility Startup Plan for adequacy and the readiness of both process and safety systems to support operations.

- DOE-G-413.3-4A – describes that "detailed" Test Plans are needed to implement the TMPs, which are required when the TRL determined during TRA's at CD-1 and/or 2 to not meet expected levels. The results of the detailed test plans are to be "closed out" with Technical Reports.

- DOE-G-413.3-16A – lists a number of plans and reports recommended at the end of the project life-cycle, they include: (a) Checkout, Testing and Commissioning Plan, (b) Transition to Operations Plan, (c) Project Acceptance Checklists, (d) Project Closeout Process (to be documented in the Project Execution Plan), and (e) Inspection and Acceptance Report.

<u>Potential Integration of TRA/TMP into Readiness and Closure Evolutions</u>:

Readiness Review Planning – can use the TMP as one of its references and completion of the actions associated with the TMP, along with the Test Reports, could be a candidate for a pre-requisite for the DOE readiness review. The TMP and Test Reports can also be used as references in the LOIs that guide the assessments done during the readiness review. If the TRA is meant to evaluate whether TRL 7A has been achieved, this should be reflected in the POA and Implementation Plan for the readiness review; if desired, this will likely impact the selection of readiness review team members. Format and content expectations for the Project Acceptance Checklists and Inspection and Acceptance Report may also be reviewed as part of readiness review planning, if integration of this effort is also planned by the Project Execution Plan and POA for the readiness review. Finally, preparation and integration planning by the Integrated Project Team (IPT) can ensure that the expectations and requirements for the Startup Test Plan, required as part of the readiness review process, meets many of the expectations of the Checkout, Testing and Commissioning Plan and Transition to Operations Plan.

Readiness Review Execution – the detailed technical reviews performed during the readiness review can serve as verification of technical adequacy of systems for both TRL and Project Closure purposes, if properly planned and documented. For ease of use, the attached Draft TRL calculator, Table A1.1, has been developed to integrate readiness review, TRL determination and several Project Closure documents. For ease of integration with the readiness review process, criteria in the attached TRL determination checklist have been split into TRL 7A for items expected to be completed before the start of the DOE readiness review and TRL 7B for those items that can only be completed after the Startup Test Plan and Transition to Operations have been completed.

Table A1.1. TRL 7 Questions for Critical Technology Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. The relationships between system and sub-systems at full scale are understood. [7A]	
M		2. Reliability, availability, maintainability, and inspectability (RAMI) analysis completed; data available for use in engineering and safety analysis. [7A]	
T		3. Test results from full-scale testing analyzed for differences between testing environment and operating environment; any inconsistencies are documented and strategies to resolve them during commissioning are defined. [7B]	
P		4. Design drawings, including as-built information, are consistent with the requirements for Final Design; Final Design information incorporated in PDSA & Technical Safety Requirements (TSR). [7A]	
P		5. Performance Baseline has been updated based on the final design and construction information, as required. [7A]	
T		6. Operating limits (including process variables and parameters) for sub-systems and components verified by testing in relevant environment at the largest scale practicable. [7A]	
P		7. Operational requirements document reflects final design and “as-built” information. [7B]	
T		8. Off-normal operating responses have been demonstrated during full-scale testing. [7B]	
T		9. Full-scale testing, verifies system technical interfaces. [7B]	
T		10. Sub-system integration has been demonstrated at the largest scale practicable. [7A]	
P		11. Scaling issues have been resolved by testing, physical modeling or analysis. [7A]	
P		12. Interface control process updated to reflect Final Design and “as-built” information. [7A]	
P		13. Acquisition program milestones have been established through Transition to Operations. [7A]	

Table A1.1. TRL 7 Questions for Critical Technology Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
M		14. Manufacturer's testing and any process/production demonstrations completed and documented; any inconsistencies are documented and strategies to resolve them during commissioning are defined. [7A]	
M/T		15. System constructed and operational feasibility has been demonstrated through demonstration of systems or sub-systems in a relevant environment at the largest scale practicable. [7A]	
P		16. Technology incorporated into applicable system design descriptions (technical and functional). [7A]	
T		17. Sub-systems verified to be compatible with operating systems, as applicable. [7A]	
T		18. Prototypical system(s) used for sub-system integration testing (prior to Startup Test program) is similar to the operational system. [7A]	
P		19. Formal configuration management program is documented and implemented. [7A]	
M/T		20. Integration of sub-systems has been verified. [7A]	
P		21. Checkout, Testing and Commissioning Plan (DOE-G-413.3-16A) and Startup Plan (DOE-O-425.1D) are complete and integrated. [7A]	
		22. Checkout, Testing and Commissioning Plan and Startup Plan adequately plan the confirmation of system operability through Hot Operations. [7A]	
P/T		23. Startup Testing integrates demonstration of safety-related requirements DSA-and TSR, in compliance with DOE STD-1189-2008. [7A]	
P		24. DSA and TSRs are approved. [7A]	
T		25. Prototypical full-scale testing with a range of simulants is complete and test deficiencies have been documented and resolutions developed. [7B]	

Table A1.1. TRL 7 Questions for Critical Technology Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T		26. Prototypical full-scale test results have been compared to laboratory and engineering-scale testing, including real waste tests, and results are consistent or inconsistencies analyzed and resolved. [7A]	
T		27. Limits for process variables and parameters and safety controls have been documented and included in applicable tests and operating procedures. [7A]	
M		28. Special tooling or procedures for operations or maintenance have been developed and demonstrated. [7A]	
P		29. Quality assurance documentation for systems is complete, incorporating Final Design and as-built information. [7A]	
T/P		30. All resulting wastes requiring disposition have been identified and verified through integrated testing at the largest scale practicable for compatibility with storage, transportation and disposal facility requirements. [7A]	
T		31. A fully integrated system has been successfully operated at full scale in the relevant environment. Target operational, performance and safety requirements have been verified. [7B]	

Appendix 2, TRA Guidance for Evaluating Process Control Systems and Process-Related Software Development

Working Draft

The guidance provided in this appendix for the conduct of a TRA of a process control system and process-related software is based upon information contained in the DoD TRA guidance[5] and recommendations from the Air Force Research Laboratory on the conduct of software TRAs[6]. This EM Guide includes a TRL calculator for TRL 6. The questions in the TRL calculator have evolved through use on several previous TRAs within DOE-EM[7].

The identification of CTEs for process control systems and process-related software is dependent on the system type and complexity. A single CTE could be used if the process control system is relatively simple, and little software is used in the system.

Points to consider when conducting a TRA of a process control system and process-related software include:

- This TRL calculator is based on achieving a TRL 6 at CD-2 or the project/program equivalent. Thus, in adjusting the calculator questions to a specific project terms such as “Preliminary Design” may need to be revised to what is expected for that project/program or stage in development.
- The TRL 6 calculator questions are intended to address both process control systems and process-related software. However, for complex process control systems, which may include a number of subsystems or a tiered architecture, an approach that evaluates appropriate sub-systems as CTEs, along with an integrated view of the system TRL determination may be appropriate. In the case of complex systems, tailoring of the attached TRL calculator is encouraged.
- The use and control of manufacturer-provided software for component configuration purposes is included.
- Completion of the TRL 6 evaluation for process control system and process-related software shares a number of attributes with completion of the TRL calculator for “Waste Processing Systems.” The WPS TRL calculators can be found in Attachment H, Tables H.8 and H.9. There are several areas of potential overlap between these two new tools (e.g., “integrated testing”) and TRA Teams performing both reviews are encouraged to integrate these efforts.

[5]U.S. Department of Defense (DoD), “Technology Readiness Assessment (TRA) Guidance,” April 2011; and “Technology Readiness Assessment (TRA) Deskbook,” July 2009.
[6]Air Force Smart Operations-21, “Software Technology Readiness Assessment Recommendations,” April 30, 2009.
[7] These have included TRAs of the software and control systems associated with the Low-Activity Waste Facility, the Laboratory, and Balance of Plant facilities at the Hanford Waste Treatment Plant (WTP), and a TRA of the Hanford K Basins Sludge Treatment Project.

Process Control/Software System – TRL 6

Table A2.1. TRL 6 Questions for Process Control System and Process-Related Software			
CTE:			
Item #	**Y/N**	**Questions**	**Basis and Supporting Documents**
1.		System/subsystem process/mechanical preliminary design and integration with any existing systems completed?	
2.		Preliminary System Descriptions are completed and approved?	
3.		Preliminary system P&IDs are approved?	
4.		Preliminary process control strategy is documented, including: operator actions/control, automatic control, and the integration of operator actions and automatic control, and data acquisition/management?	
5.		System functional requirements are documented?	
6.		System process control/software architecture and logic are established?	
7.		Operating environment definition finalized?	
8.		Have test requirements been specified to verify the proper use and function of: process controls; process-related software, including manufacturer-provided software used to configure relays, component controls and sensors; and integration with any existing control systems?	
9.		Process system process control/software has been formally placed under configuration control.	
10.		Process system controls and process control software is complete to support preliminary design.	
11.		Has the proper use and function of manufacturer-provided software, used to configure relays, component controls and sensors, been confirmed through system design reviews and system testing?	

Table A2.1. TRL 6 Questions for Process Control System and Process-Related Software			
CTE:			
Item #	**Y/N**	**Questions**	**Basis and Supporting Documents**
12.		Have impacts of the process control strategy (equipment, software, operator actions) on reliability, availability, maintainability, and inspectability—including the avoidance of single-point failures—been evaluated and documented?	
13.		Process system controls, process control software system, and process control strategy demonstrated at range of anticipated normal and off-normal conditions simulated process operations.	
14.		Validated and verified process control/software test exception/test discrepancies have been documented and resolved for normal and off normal simulated process operating conditions.	
15.		Has the process control strategy been verified for subsystem operational integration?	
16.		Equipment component and system set point ranges have been established.	
17.		Does the preliminary design address the integration of normal process control/software and safety process control/software?	